1894.

NEW ZEALAND.

THE GOLDFIELDS OF NEW ZEALAND:

REPORT ON ROADS, WATER-RACES, MINING MACHINERY, AND OTHER WORKS IN CONNECTION WITH MINING.

Presented to both Houses of the General Assembly by Command of His Excellency.

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REPORT ON ROADS, WATER-RACES, MINING MACHINERY, AND OTHER WORKS IN CONNECTION WITH MINING.

Presented to both Houses of the General Assembly by Command of His Excellency.

Mr. H. A. GORDON, F.G.S., Inspecting Engineer, to the Hon. A. J. CADMAN, Minister of Mines.

SIR,— Mines Department, Wellington, 24th July, 1894.

I have the honour to submit my annual report, for the year ending 31st March last, on the different works undertaken and constructed either by the Mines Department or by subsidies paid to local bodies; also, on Schools of Mines, water-races controlled by the department, and generally on the development of the mining industry throughout the colony.

The works are classified under the following heads: "Subsidised Roads and Tracks," "Roads constructed by Direct Grants," "Prospecting," "Schools of Mines," "Water-races," "Gold-mining," "Quartz Workings," "Geology, Resources, and Future Prospects of the Thames Gold-field," by James Park, F.G.S., "Alluvial Mining, including Hydraulic Sluicing and Dredging," "Coal-mining," "Mining Machinery," "Patents applied for Processes in connection with Gold-mining," "The History and Progress of the Cyanide Process for the Treatment of Gold- and Silver-ores," "Genesis of Ores," "Examination Papers recently used in the Mine-managers' Examinations," and "Statistical Tables showing the Value of Works constructed," and list of mining managers.

SUBSIDISED ROADS AND TRACKS.

Under this heading, works have been authorised to the value of £5,038 11s. 6d. The net expenditure for the year was £2,718 17s. 8d., and there is still a liability on these works of £5,576 10s. 7d.

ROADS CONSTRUCTED BY DIRECT GRANTS.

During last year new works have been authorised to the extent of £18,418 19s. 2d. The net expenditure on works of this class during the same period has been £15,056 0s. 11d., and there is still a liability owing of £13,013 18s. 5d.

WORKS UNDERTAKEN BY PROSPECTING ASSOCIATIONS AND COMPANIES.

The total amount authorised during last year for prospecting purposes was £2,245 19s. 4d., and the net expenditure for the same period was £1,591 10s. 5d., leaving the liabilities at the end of March last at £1,027 7s. 11d.

A detailed list of all the works undertaken is annexed at the end of the report.

SCHOOLS OF MINES.

As year after year passes by, the work done by the schools of mines is more appreciated. The necessity of a technical education on subjects in connection with mining is now felt by some of those who a few years ago considered it a mere waste of time to acquire technical knowledge, and that practical experience was the only thing required to carry on mining operations. In all older mining countries it has been found necessary to have schools where young men can be properly trained and receive a sound mining education, in addition to having practical experience in the working of mines; and from actual experience in the working of gold- and coal-mines in New Zealand, this class of education is as much wanted here as it is in older mining countries. The

different minerals the miner finds in pursuing his ordinary avocation, the combination of the various metals, and the complex ores that are met with, all demand a training of no ordinary degree to be an expert in mining. To be able to successfully carry on mining operations in all its branches a man must not only have a large practical experience in actual workings of mines, but he also must have a general knowledge of the chemistry of metals, in order that he may analyse and ascertain the percentage of metals the ore contains; he must have a knowledge of mineralogy before he can identify the form and crystallization of the various mineral ores; a knowledge of geology to be acquainted with faults, slides, and heaves, to be able to determine the method of again discovering lodes which may be cut off and displaced by fault-movements, and to have a knowledge of the composition of the country rocks in which mineral ores are found; a knowledge of the composition of gases, their deleterious effects on animal life, and of their dilution so as to render them harmless, so as to be well acquainted with the principles of ventilation; a knowledge of metallurgy, so as to be able to fully understand the best and most economic methods of extracting the various metals from their ores; and he also must have a fair knowledge of mathematics before he can understand the principle of, and carry out underground surveys. It will therefore be seen that any one who adopts mining as an avocation requires a large and varied technical education. Indeed, to be thoroughly acquainted with every phase of mining requires a higher technical education than almost any other profession.

In order to encourage students attending schools of mines, the Hon. the Minister of Mines has offered to give annually for competition three scholarships at the Otago University, of the annual value of £50 to students residing more than three miles beyond the boundaries of the City of Dunedin, and £30 to those residing within the boundary as stated; the scholarships to be tenable for three years, or for such other less period as may at the discretion of the Minister appear to be necessary.

The examination of students will be held in the month of December in each year, at the Thames, Reefton, and Dunedin, on the following subjects: Theoretical chemistry, practical chemistry, metallurgy of gold and silver, mining, ventilation of mines, general and mining geology, land and mining surveying and drawing. No scholarship will be awarded to a candidate who does not obtain 75 per cent. of the marks in each subject. All candidates applying to be examined to forward a fee of 10s. to the Under-Secretary of the Mines Department not later than the 1st of November in each year. The examination papers to be prepared by the examiners of the Schools of Mines at the Thames and Reefton. The Minister, however, reserves the right to cancel any scholarship should the holder thereof attend irregularly or be reported for idleness or bad conduct; and no candidate will be allowed to compete for a scholarship who has not been attending a school of mines within the colony for at least a period of two years. This ought to give a high incentive to students to study and prepare themselves to compete for a scholarship.

THAMES SCHOOL OF MINES.

The average number of individuals attending the school last year was ninety-one, as against 105 for the year previous. Of the number last year, forty were registered students, and fifty-one pupils attending Saturday science lectures. During the year thirteen parcels of ore have been tested at the plant attached to the school, in lots from 320lb. up to 4,125lb., the aggregate weight of ore tested being 21,610lb., as against 22,819lb. for the year previous. The value of the ore treated was £275, or about £28 10s. per ton, and the average recovery of bullion was about 78 per cent. During the last year a cyanide plant has been added, which will in future enable ores suitable for leaching by the Cassel process to be treated. The whole of the parcels of ore tested last year at the plant attached to the school, with one exception, was crushed dry, and treated by pan-amalgamation.

Mr. F. B. Allen, M.A., B.Sc., who was temporarily employed, has been permanently appointed as assistant to Mr. Park. The appointment has given every satisfaction to the Committee, who speak highly in his favour. He has taken over the class of mechanical drawing and mathematics, and assists Mr. Park with the classes in chemistry and assaying. This has relieved Mr. Park of a great deal of the work, and given him more time to devote to field-surveying and geology.

The Committee of the school has decided to grant diplomas to mining engineers, on condition that they first shall pass an examination for mine-managers' certificates under the Mining Act, and also under the Coal-mines Act, and shall attend the school for another year and pass a satisfactory examination in engineering surveying, designing, and constructing, land- and mine-surveying, geodetic surveying, applied mechanics, hydraulics, mechanical drawing, general and mining geology, mineralogy, mathematics, and electricity and magnetism.

It is questionable if it is wise to grant diplomas of mining engineers to young men who have no practical experience in the working of mines, and who, notwithstanding, have acquired the theory of mining and all subjects connected with it. There are many things that appear totally different when the inexperienced man commences to put his theory in practice, and he finds, although he may have passed his theoretical examination with credit, he is only entering his apprenticeship in his profession. Before a man can get a diploma as a mining engineer in some of the schools of mines in America he must, in the first instance, have a fair education, such as one would require to pass an examination for matriculation to a university. At the school of mines at the College of Montana, Deer Lodge, Montana, United States, the course of instruction is as follows: First year—Trigonometry, analytics, general chemistry, German or some selected language, qualitative analysis, botany, and English. Second year—Analytics, calculus, chemical physics, chemical philosophy, physics, quantitative analysis, descriptive geometry, metallurgy, crystallography, and theoretical mineralogy. Third year—Calculus, mechanics, metallurgy, geology, mechanical engineering, mining engineering, civil engineering, strains in structures, lithology, and mineralogy. Fourth year—Assaying, railroad engineering, strains on structures, ore-dressing, hydraulic engineering, properties of metals, economic geology, applied chemistry, sanitary engineering, heating and

ventilation, graphical statics, and lithology. During the vacation at the end of the third year the students have to visit mines and make a study of them; and during the fourth year they all write a memoir giving a detailed description of the mines visited, illustrated with drawings made carefully to scale.

At Columbia College, New York, the course of instruction is somewhat similar to that at Montana, but it is necessary for the students to work in the mines at the close of the third year's vacation.

At the Michigan Mining School only mining is taught, and the tuition goes on for the most of the year. Hitherto the course of study has only occupied three years, but it is now proposed to extend the course to four years for a mining engineer. The subjects taught are somewhat similar to those previously mentioned.

At the Colorado State School of Mines the course of instruction for the first two years is the same for either a civil engineer, metallurgical engineer, mining engineer, or electrical engineer. The special courses for mining engineers in the third and fourth years are as follow: Third year—Analytical geometry, differential and integral calculus, civil engineering, primary and secondary batteries, mining, quantitative analysis, mechanical drawing, metallurgy, mechanics, theory of strains, mining engineering, ore-dressing, electrical units, and vacation memoir. Fourth year—Integral calculus, kinematics, mechanical drawing, mechanics, dynamics, theory of strains, economic geology, metallurgy, dynamo-electric machinery, distribution of electricity for lighting, thermodynamics, plans, constructions and estimates, mechanical engineering, electricity in mining, thesis work (including plans, estimates, and drawings), and long-distance transmission of power.

At the Royal Saxon Academy of Mining, Freiberg, the work of the practical course has to be taken as follows: (1) Surface work for eight or nine weeks in ore-dressing and -concentration; (2) the time remaining to be spent in work underground, and also in visiting, under the direction of the professor of mining engineering, other mines in the district. The full course of instruction extends over a period of four years: First year—Mathematics, descriptive geometry, spherical trigonometry, physics, inorganic chemistry, mineralogy, crystallography, drawing and planning. Second year—The higher parts of the above subjects, mechanics, mining geology, palæontology, economic geology, blowpipe analysis, and mechanical drawing. Third year—Surveying, mining engineering, metallurgy, building construction, and machine-drawing. Fourth year—Surveying, general and mining law, mining and metallurgical buildings, calculations, and statistics, political economy, sanitation, and technical electricity. At the close of the course the student sits for a final examination, and, in the event of passing, obtains a diploma.

Enough has been said to show that in other countries a mining engineer has to have a careful training, and if the Committee have decided to grant diplomas to mining engineers, a similar course of instruction should be given as at other places, and in addition to the subjects already mentioned there should be dredging as applied to mining, and hydraulic elevating. One year's course of study is not sufficient for a mining engineer to acquire a knowledge on all subjects relating to his profession after he has passed an examination for mine-manager, for, after all, this examination requires only an elementary education, and no diploma should be issued that is not of equal value to those granted in other countries. A gentleman with the diploma of a mining engineer should be a man in whom investors in mines can place full reliance in his knowledge, judgment, and accuracy of his estimates of all works in connection with mining, and it is to be feared that the course of training proposed by the Committee of the Thames School will not meet the requirements sought to be attained.

The following is the report of James Park, F.G.S., Director and Instructor of the Thames School, on the progress made for the year ending the 31st March, 1894:—

I have the honour to report that the instruction and teaching at the School of Mines during the past year have met with the marked success of former years. The ready employment which our students obtain, and the numerous inquiries for their services from all parts of New Zealand, are a sufficient guarantee that the instruction is not only theoretical, but also of a sound practical character. The subjects of instruction may be divided into three distinct departments—namely, those of metallurgy, mining, and surveying. In these I endeavour to make the practical work of the advanced students of a technological and professional rather than a class-room character. This procedure has many distinct advantages. In the first place, the students are encouraged to battle with and master abstruse theoretical details when they can see the practical application lying behind them; and, in the second place, they always find it a distinct advantage to be able to take their place in the laboratory and melting-room of the bank, the reduction-mill, quartz-mine, or go into the field as a mining or engineering surveyor, and perform their work in a professional and workmanlike manner.

During the past four years twenty-three of our students have obtained employment in various capacities connected with mining, ten as mine-managers at salaries ranging from £200 to £350 a year, six as metallurgists in reduction-works where the Cassel cyanide process is in use, from £125 to £200, and seven as metallurgical assayers from £120 to £150. It gives much pleasure to state they have always given their employers much satisfaction. On a recent date, Mr. Alfred James, the general manager of the Cassel Company for New Zealand, in a letter inquiring for two students to take charge of the new cyanide plants being erected at Waitekauri, referred in very complimentary terms to the work of our students in the cyanide plants at Waihi and Waitekauri. He stated that he had advised the head office of his company in Glasgow that it was unnecessary and inexpedient to send metallurgists from Britain when such capable men were being turned out at the Thames School of Mines.

Since the beginning of 1890 twenty-four students have been prepared for the Government examination for mine-managers. Of these twenty-one have secured first-class certificates, and when the results of the last examination are known it will be found that the remaining three have

given a good account of themselves. Besides these, four students have passed the prescribed Government examination for engine-drivers' certificates.

Students brought up in a mining community are always the most apt of pupils. Most of them have been engaged in practical battery- and mine-work from their youth. They are consequently already well acquainted with all the details and mechanical parts of a battery, the construction and timbering of shafts, drives, &c., and the working parts of pumping and winding machinery. When they begin their underground surveys they are already familiar with their surroundings, and all possess a knowledge of the phraseology of milling and mining. From their own personal experience of the behaviour of reefs in the mines, they are quick to perceive and ready to apply the laws relating to the recovery of lost lodes. The skill with which the intelligent miner-student handles the theodolite and executes his plans, together with his quickness to master the solution of triangles and trigonometrical calculations of areas, are matters that still surprise me.

The most notable event in connection with our experimental battery has been the erection of a most complete plant for the treatment of ores by the McArthur-Forrest cyanide process. The manager of the Cassel Company has written in terms of approbation concerning its design and construction. It will prove of great service to the public and an inestimable boon to our metallurgical students, who will now be able to obtain a practical as well as a theoretical knowledge of the working details of the process before leaving the school.

The acute depression which has prevailed in mining at the Thames during the past two years, and the large number of students who have completed their course of study and graduated, have at last affected the attendance at the school. The average number of registered students for 1892–93 was fifty-two, and for the past year forty. The number of students attending the different classes in the different terms are given in the following tabulated form :—

TABLE OF ATTENDANCE for Year ending 31st March, 1894.

Name of Class.	1893.			1894.
	First Term.	Second Term.	Third Term.	First Term.
Registered Students.				
Practical assaying	26	29	27	15
Practical chemistry and laboratory practice	23	21	17	9
Theoretical chemistry...	23	21	17	9
Metallurgy of gold and silver	...	...	29	...
Mineralogy and blowpipe determination...	7	8	9	7
General and mining geology	7	8	9	7
Mining, applied mechanics, hydraulics	13	14	14	10
Land- and mine- surveying	15	14	17	16
Engineering surveying	...	...	...	5
Practical astronomy	...	...	...	5
Mechanical drawing	9	5	5	2
Mathematics	...	...	16	8
Designing and construction	...	...	...	7
Saturday Science Lectures.				
Elementary mechanics	61	...	...	...
Sound, light, and heat	...	50	...	...
Electricity and magnetism	...	...	54	...
Experimental chemistry	...	...	...	37
Total attendance at all classes	184	170	214	137
Registered students...	43	42	43	33
Total individual students	104	92	97	70

At the beginning of the present year the Committee of the school decided to grant the diploma of mining engineer. Hitherto the only certificates issued by the school have been class certificates of three grades based on the results of the annual examinations. Students who wish to graduate for the diploma of mining engineer will be required to possess a first-class certificate as a mine-manager, gained by examination under the regulations of "The Mines Act, 1891," or "The Coal-mines Act, 1891," and, after a further period of study extending over not less than one year, will be required to pass a satisfactory examination in general and mining geology, mineralogy, mathematics, hydraulics, land-surveying up to requirements of Survey Department, engineering surveying, mechanical drawing, designing and construction, and practical astronomy with a view of determining meridian, latitude, and time.

Five passed mine-managers have already commenced the necessary studies with me, and up to the present time very satisfactory progress has been made. The instruction in practical astronomy has so far been confined to class-lectures, but as soon as our new transit-theodolite, now some time ordered from London, arrives, individual instruction will be given in the field

observations. The geodesic station which was established on Mount Pleasant in 1892 will now be of great service to this class.

The annual examinations were conducted in the last week in November and first week in December. The papers were prepared and printed in Wellington, and forwarded to Mr. Bruce, the secretary of the school, who kept them in his possession in separate sealed packets until the specified time for each examination. The examinations were supervised by myself and Mr. F. B. Allen, M.A., B.Sc., my assistant. At the end of each examination the papers of answers were immediately placed in packets, sealed, and handed to the secretary. Mr. Henry A. Gordon, F.G.S., M.A., Inst. M.E., was the examiner in mine- and land-surveying, mining, explosives, and ventilation, pumping and winding, metallurgy and mineralogy; Mr. William Skey in assaying and chemistry; Mr. A. McKay, F.G.S., in general geology; while the papers in the physical sciences were set by myself.

Sixty-eight students presented themselves for examination, and of these thirty-four secured first-class certificates, twenty-three second-class, and twenty-seven third-class. The results compare favourably with those of former years, and in most subjects the standard was well maintained. There was a distinct falling-off in the percentages obtained in practical assaying (dry) and in the junior theoretical chemistry class, but this was balanced by a very marked improvement in the metallurgy of gold and silver, practical chemistry (inorganic), practical chemistry (organic), and land- and mine-surveying.

The President's medal was gained by Mr. A. R. Carnie with the high average of 92 per cent. in eight different subjects, and the McCulloch medal by Mr. J. R. Robinson with 84 per cent. in six subjects, while Mr. George Fleming followed close with 80 per cent. in eleven subjects.

Results of Annual Examinations, 1893–94.

Subject of Examination.	First Class.	Second Class.	Third Class.	Failed.	Total.
General geology	1	...	2	...	3
Mineralogy	1	2	...	...	3
Metallurgy of gold and silver	5	3	1	...	9
Mining	...	...	1	...	1
Explosives and ventilation	...	...	1	...	1
Theoretical chemistry (junior)	...	...	2	...	2
Theoretical chemistry (senior)	2	1	2	...	5
Elementary mechanics	6	..	...	...	6
Practical assaying (dry)	1	6	5	...	12
Practical assaying (wet)	2	1	2	...	5
Practical chemistry (inorganic)	2	...	1	...	3
Practical chemistry (organic)	2	...	2	...	4
Land- and mine-surveying	...	2	...	...	2
Sound, light, and heat	4	2	...	...	6
Magnetism and electricity	4	2	...	...	6
Laboratory practice (assaying)	3	2	7	...	12
Laboratory practice (practical chemistry)	1	2	1	...	4
Totals	34	23	27	...	84

Mr. Carnie has already received a good appointment as analyst to a guano trading company near New Caledonia.

Practical Assaying.—This still continues to be a largely-attended class. The ores found in the different parts of the Hauraki goldfield are of a very complex and varied character, and it requires a long and varied course of training to be able to determine the proper fluxes so as to obtain the best results. Almost any assayer can obtain fairly good results from clean rich ore, but it requires a practised hand and skilful manipulation to secure accurate results from complex sulphide ores worth only a few shillings per ton. In the treatment of ores by the cyanide process ultimate success depends very greatly upon accurate assaying. An assayer in a reduction-works or a bank must not only be reliable but also quick, so as to prevent an accumulation of work on his hands.

During the past two terms a large number of laboratory tests have been made by some of the metallurgical students, and hereunder I give a few of the results:—

Alburnia Concentrates.

	Assay-value per Ton. Oz. dwt. gr.	Percentage of Extraction.
Bullion	45 14 23	70·0
Gold	5 5 21	76·2
Silver	40 9 1	69·2
Value	£27 5 0	74·6

Operator, G. Fleming.

These concentrates contained a large proportion of decomposing sulphides, and when subjected to a special preliminary treatment before leaching the following results were obtained: Extraction —gold, 91 per cent.; silver, 25 per cent.; value, 85 per cent.

Waitekauri Ore.

	Assay-value per Ton. Oz. dwt. gr.	Extraction: 1·25% KCN.	Extraction: 1·5% KCN.	Extraction: 1·80% KCN.	Extraction: 2% KCN.
Bullion ...	28 12 4	95·6	90·8	94·5	91·2
Gold ...	8 6 9	84·8	81·8	93·9	86·4
Silver ...	20 5 19	93·3	94·4	96·1	93·2
Value ...	£36 5 10	85·6	83·1	94·2	87·1
Operator		G. Fleming.		G. Peel.	

This was a hard, slightly ferruginous quartz. It contained only a trace of metallic sulphides.

Practical Chemistry (Organic and Inorganic).—A large amount of useful work was undertaken by the advanced students last year. Good results were obtained in the analysis of rocks, soils, waters, limestones, coals, guanos, and artificial manures. A number of estimations were also made of the alcohol in beers, wines, spirits, &c. Much arduous and painstaking work was undertaken by Mr. W. Climo of this class, in the solution of the treatment of complex sulphide ores, such as those of Broken Hill. He was so far successful that he was invited to go to Sydney and demonstrate his process, and he is now in that place superintending the erection of a large experimental plant for this purpose. His process contains all the elements of success, and if it can be proved to be practicable on a large scale will cause a great revival at Broken Hill and other places where a low percentage of silver and lead is associated with a large proportion of zinc-blende and other refractory minerals.

Among the other students of this class who have received appointments during the past year are—A. R. Carnie, analyst to Guano Company; B. Wolffe, manager Cassel cyanide plant at Golden Cross Mine, Waitekauri; A. T. Day, assayer at Cassel plant, Waihi; R. Mellett, Cassel plant, Komata, Waitekauri; and W. Carpenter, assistant assayer to Bank of New Zealand, Paeroa.

Some of the more interesting analyses performed last year under my own personal supervision are as follow:—

Complex Sulphide, Broken Hill, N.S.W.; analysed by W. Climo.

Silica ...	10·67
Lead ...	22·54
Iron ...	9·21
Zinc ...	34·04
Arsenic ...	3·12
Sulphur ...	20·35
Silver and gold ...	0·10
	100·13

Wolfram, Tasmania; analysed by W. Climo.

SiO_2 ...	3·25
FeO ...	18·71
MnO ...	4·90
WO_3 ...	73·56
	100·42

Scheelite, Lake Wakatipu; analysed by W. Climo.

SiO_2 ...	31·17
CaO ...	13·94
WO_3 ...	53·86
	98·97

Analysis of Coals, by R. Mellett.

	Kawakawa.	Newcastle.
Hydro-carbons ...	29·70	33·42
Fixed carbon ...	61·70	59·10
Water ...	7·10	3·08
Ash ...	1·50	4·40
	100·00	100·00
Evaporative power in pounds ...	8·02	7·68

Remarks.—These are both fine coals. The Newcastle yields a hard coke. Bright, shining, somewhat friable.

Analysis of Kawakawa Coal, by C. H. Taylor.

	First.	Second.
Hydro-carbons ...	27·54	27·88
Fixed carbon ...	64·32	64·18
Water ...	6·42	6·50
Ash ...	1·72	1·44
	100·00	100·00

Evaporative power, 8·361b.

Colour black; brittle; non-caking; ash white; practically free from sulphur.

Analysis of Kamo Coals, by A. T. Day.

	Upper Seam.	Lower Seam.
Hydro-carbons	47·42	45·38
Fixed carbon	35·31	34·16
Water	12·11	14·22
Ash	5·16	6·24
	100·00	100·00
Evaporative power in pounds	6·16	5·90

These are ordinary pitch-coals; non-caking; colour blackish-brown; brittle; friable; ash white; sulphur, trace only.

Water from Waitakururu Hot Springs; analysed by F. B. Allen, M.A., B.Sc.

	Gr. per Gal.	Gr. per 100,000.
Sodium chloride	21·434	30·620
Calcium sulphate	0·862	1·230
Magnesium sulphate	0·060	0·080
Aluminum sulphate	0·607	0·870
Silica	4·354	6·220
Organic and volatile	2·730	3·900
Total solids	30·047	42·920

Reaction, neutral to litmus. This is a slightly-chlorinated swamp-water. The proportion of organic matter is high, and renders it unwholesome for drinking purposes.

Brown's Island Guano; analysed by C. H. Taylor.

Moisture at 100° C	7·60
Organic matter and ammonia	31·38
Silica and insoluble matter	7·54
Tricalcic phosphate	20·39
Calcium sulphate	21·91
Magnesium sulphate	2·75
Sodium sulphate	6·85
Potassium sulphate	1·84
	100·26

This manure has been artificially loaded with sulphate of lime.

Limestone Core from Diamond Drill, Woolley's Hill, Kamo; analysed by A. T. Day.

Carbonate of lime	80·32
Carbonate of magnesia	3·07
Alumina	12·62
Iron oxides	Trace
Silica	Trace
Water	2·89
	98·90

Guano retailed in Auckland; analysed by W. Climo.

Moisture at 100° C	7·10
Organic matter	30·07
Ammonia	5·50
Insoluble matter	8·75
Tricalcic phosphate	25·78
Calcium sulphate	13·61
Magnesium sulphate	2·16
Soda	7·00
Potash	0·52
	100·49

This is an inferior guano, artificially made up to resemble those of better quality.

Determination of Alcohol in Whiskeys sold at Pacific Hotel, Thames; analysed by W. Climo.

Brand.	Alcohol, by Weight.	By Volume.	Proof Spirit.
"Peat Moss"	41·40	48·84	85·62
"Galley"	41·40	48·85	85·64
"Peat Moss" (travellers' sample) ...	47·77	55·56	97·36

These are pure spirits, containing no injurious ingredients.

Determination of Alcohol in Beers, Wines, and Spirits sold at Thames.

Brand.	Alcohol, by Weight.	By Volume.	Proof Spirit.	Analyst.
Usher's Whiskey (sold over bar)	43·100	50·670	88·70	A. R. Carnie
Peach Wine (local make) ...	10·770	13·330	...	"
Wendel's Port Wine (Auckland make)	8·640	10·520	...	W. Climo
Speight's Dunedin Beer ...	5·430	6·780	...	"
Ehrenfried's Beer	5·810	7·250	...	A. R. Carnie
Musket's Hop-beer ...	0·470	0·600	...	"
Musket's Ginger-beer ...	2·890	3·620	...	"
Menzies' Hop-beer ...	0·686	0·862	...	"
Menzies' Ginger-ale ...	0·083	0·112	...	"

Copper-ores from Great Barrier Island; analysed by A. R. Carnie.

	No. 1.	No. 2.
Silica	00·00	0·00
Copper	32·00	4·32
Iron	29·92	41·80
Sulphur	32·50	47·80
Water and CO_2	7·40	5·40
	101·82	99·32

Both ores contained copper-pyrites and a little copper carbonate. No. 2. was principally composed of iron-pyrites.

Antimony-ore; analysed by F. B. Allen, M.A., B.Sc.

Insoluble gangue	12·40
Antimony (metal)	63·36
Sulphur }	24·24
Oxygen }	
	100·00

This ore was composed of the sulphide (antimonite) encrusted with a thick layer of the yellow oxide cervantite. Locality: Waikari, Bay of Islands.

Manganese Oxides from Waiheke Island; analysed by A. R. Carnie.

	No. 1.	No. 2.
Manganese oxides	89·90	88·90
Iron oxides	6·20	6·20
Water	2·76	2·76
Insoluble matter	0·51	0·50
	99·37	98·36

These are valuable ores. They contained no phosphorus.

Brown-coals from Reefton; analysed by the Director.

	No. 1.	No. 2.
Hydro-carbons	40·08	41·33
Fixed carbon	41·21	40·42
Water	12·86	13·15
Ash	5·85	5·10
	100·00	100·00
Evaporative power	5·361b.	5·251b.

These are valuable coals for domestic and steam purposes.

Kerosene-shale from Kaikohe, North Auckland; analysed by the Director.

This shale yielded by destructive distillation 14 per cent. of crude oil, equal to 31·36gal. per ton. Colour, yellowish-brown or buff. This is a valuable shale, and if it exists in large quantities could be turned to commercial account.

Sample of Jamesonite from near Wellington; analysed by the Director.

Lead	72·10	Bullion, 358oz. 16dwt. per ton—Gold, trace; silver, 358oz. 16dwt. per ton. Value, £35 16s. per ton.
Antimony	12·76	
Iron	Trace	
Sulphur	13·70	
Silver	1·00	
	99·56	

This is said to be from a lode near Wellington. It is a most valuable ore, and is the first known occurrence of Jamesonite in New Zealand. A large proportion of the antimony is replaced by lead, and in its argentiferous character it closely resembles the Jamesonite found at Mount Zeehan, in Tasmania.

Land- and Mine-surveying.—This class was originally started for the instruction of those preparing themselves for the Government examination for mine-managers. It is now numerously attended, and many of the students devote themselves to their studies with great zeal. A large number of class surveys have been made during the year on the high hills behind the town, the areas ranging in size from a quarter of an acre to 40 acres. The ground is steep, very broken, and in most places covered with dense manuka-scrub; but, notwithstanding these physical disadvantages, the closure of most of the surveys has been exceptionally accurate, and far within the limits of error allowed by the Survey Department.

A number of underground surveys were successfully undertaken by the students, and under my supervision the true meridian was carried down to the No. 4 level of the Mary Ann shaft of the Waiotahi gold-mining lease. Two different methods were used, and there was less than a minute of arc of difference between them. In the first method two wires were suspended in the shaft, one in each winding compartment, and the meridian carried below by means of triangulation. In the second method the two wires were suspended in one compartment, and the meridian carried below by protracting the bearing of the line between them. Every precaution was taken to insure success, and the results prove the accuracy of both methods when carefully undertaken.

The students who went up for the school and Government examinations made independent surveys of areas not less than 20 acres in extent. All the surveys were conducted with the theodo-

lite, and their accuracy was tested by circuit traverse or minor triangulation. Topographical plans were also furnished, as well as a plan and sections showing the reef, stopes, and underground workings of some well-known mine.

During the present year I have instructed the advanced students in setting out the opposite angles of roads, obstacles to chaining and alignment, division of land, &c. The practical use of a knowledge of surveying is now freely admitted by all our leading mine-managers.

Mining.—The instruction in this subject covers all the course of instruction required by candidates for Government mine-managers' certificates, excepting surveying. It includes mining, geology, mineralogy, dynamics, and classification of lodes; construction and timbering of shafts, chambers, drives, &c.; construction of dams; explosives, ventilation, pumping and pit-work, hauling and winding, strengths of materials, hydraulics, and applied mechanics. Special attention is given to the recovery of lost lodes, and to hydraulics. A knowledge of these is indispensible to every well-informed mine-manager and mining engineer.

Diploma of Mining Engineer.—This diploma is open only to students of the School of Mines who have gained by examination a first-class certificate as a mine-manager after a two years' course of instruction, and who shall thereafter pass a satisfactory examination in the following subjects after a further period of one year's study at the school:—

(*a.*) Engineering Surveying.—(1.) Levelling with level, theodolite, reflecting-level and barometer; the level-book; grading; sections, &c. (2.) Road and railway curves. (3.) Tunnelling, setting out and excavating. (4.) Contents of earthwork, estimates, &c. (5.) Preparation of plans and specifications.

(*b.*) Designing and Constructing.—(1.) Designing and preparing estimates of flumes, trestles, bridges, culverts, aqueducts, poppet-legs, battery sites and foundations, &c. (2.) Preparing working-plans and tracings of same.

(*c.*) Land- and Mine-surveying.—(1.) Compass surveying. (2.) Theodolite surveying. (3.) Obstacles to angular surveying and alignment. (4.) Mapping surveys and calculating areas. (5.) Road surveys and setting off road-angles. (6.) Division of land. (7.) Topographical surveys and plans.

(*d.*) Geodetic Surveying.—(1.) Triangulation, major and minor. (2.) Astronomical problems and definitions. (3.) Fixing the true meridian. (4.) The determination of latitude. (5.) The determination of time.

(*e.*) Applied Mechanics.—(1.) Strength of materials. (2.) Strains on materials. (3.) Horse-power of engines for batteries, &c.

(*f.*) Hydraulics.—(1.) Flow of water from orifices. (2.) Horse-power of water-motors, &c.

(*g.*) Mechanical Drawing.

(*h.*) General and Mining Geology.

(*i.*) Mineralogy.

(*j.*) Mathematics.

(*k.*) Electricity and Magnetism.

Laboratory.—The number of assays and analyses performed for the public during the past year amounted to 206, most of which were determinations for gold and silver. This shows a great falling-of compared with the returns of last year, a result mainly due to the prevailing depression and the assays performed by private assayers. The investigation of one poison case was undertaken by myself, as well as a number of alcohol determinations for the Police Department.

Experimental Plant.—The machinery and appliances are all in good working-order, and several much-needed improvements have been effected during the year. The cyanide plant recently erected in the school battery is most complete, and substantial in construction. It consists of an agitator on an elevated platform, and below this a circular percolating vat 3ft. 3in. deep and 5ft. 3in. in diameter. The percolator is fitted with a lattice filter-frame, and connected directly with the zinc-extractor, and also with a large steel vacuum-cylinder, which is in its turn connected with the zinc-extractor. The cylinder is exhausted by a fine single-action air-pump, which is surrounded by a cold-water jacket. Below the level of the floor there are two large circular sumphs to receive the spent solutions. The sumphs are protected by a close-timbered platform. On an elevated platform situated over the sumphs there is a Douglas solution-pump, connected with both sumphs and with the percolator and agitator. The whole of the cocks and numerous pipe-connections are disposed so as to facilitate the treatment of ores either by agitation or percolation. The agitator and air-pump are actuated by pulleys on secondary shafts connected by pulleys with the main shaft. All the vats, machinery, and appliances were constructed and erected by Messrs. Price Brothers, of the Thames, upon whom the work reflects the greatest credit. Several parcels of ore are already awaiting treatment by this plant, and numerous inquiries have already been received from many parts of the peninsula and from the South Island.

The number of parcels of ore treated by the Washoe process last year was thirteen, compared with twenty-one for 1892–93. As in former years, all the operations in connection with the treatment, from the drying of the ore to the final melting and valuation of the bullion, were performed by the school students without any outside aid. The method of treatment and the results are shown in the following tabulated statement. It will be seen that, although fewer parcels of ore were treated than in 1892, the total weight of ore put through was almost the same, the exact figures being—for 1893–94, 21,610lb., equal to 9·65 tons; and for 1892–93, 22,819lb., equal to 10·2 tons. Omitting the ores forwarded by Mr. Montgomery Davis from Kopukauaki Bay, which were smelting-ores, the average percentage of recovery amounted to 77·9 per cent., as compared with 78·3 per cent. for the preceding year. The sterling value of the bullion extracted from the parcels of ore treated during the year was about £275, and for the previous year about £1,000.

TABULATED STATEMENT showing Parcels of Ore treated at the School Experimental Plant during 1893–94.

Name of Mine and District.	Description of Ore.	Weight of Ore.	Assay-value of Ore per Ton.				Method of Crushing.	Method of Treatment.	Bullion saved.	Percentage recovered from Amalgamated Copperplates.			Percentage recovered by Pan-Amalgamation.			Total Percentage recovered from all Sources.		
			Bullion.	Gold.	Silver.	Value.				Gold.	Silver.	Value.	Gold.	Silver.	Value.	Gold.	Silver.	Value.
		Lb.	Oz. dwt. gr.	Oz. dwt. gr.	Oz. dwt. gr.	£ s. d.			Oz. dwt. gr.									
Mr. McNeil, Ocean View Matarangi	Clean, friable ..	2,180	5 15 23	3 3 0	2 12 23	13 0 0	Dry	Raw pan-amalgamation ..	6 0 0	..	..	..	88	87·5	88	88	87·5	88
Jas. Corbett, Marototo ..	Mullocky ore ..	1,750	57 14 6	2 0 8	55 13 22	16 5 7	„	Pan-amalgamation with chemicals	19 15 0	..	..	..	67·7	42·4	53·5	67·7	42·4	53·5
Angus McNeill, Matarangi	Ore, clean, friable ..	320	6 3 16	1 10 15	4 13 1	6 16 2	Wet	Copperplates and pan-treated tailings	0 16 21	24	4·1	22	73·7	56·4	72	97·7	60·5	94
Kapai Mine, Kuaotunu ..	Clean, friable ..	4,125	9 14 2	6 6 1	3 8 1	25 17 6	Dry	Pan-amalgamated ..	11 14 0	..	..	..	64·2	43·3	63·3	64·2	43·3	63·3
Messrs. McLiver, Puiri ..	Mullocky ore, clean ..	2,475	11 4 7	7 16 7	3 8 0	31 15 0	„	Pan-amalgamated ..	11 10 0	..	..	..	84·6	80·7	84·3	84·6	80·7	84·3
Mr. Montgomery Davis, Koputauaki, Coromandel	Mullocky ore with complex sulphides	2,080	33 7 23	1 12 18	31 15 7	11 6 3	„	Pan-amalgamated with chemicals	5 15 0	..	..	..	25	17·3	21·2	25	17·3	21·2
Ditto	Mullocky ore ..	680	23 6 6	1 0 4	22 6 2	7 7 6	„	Ditto	1 12 0	..	..	..	35	21	28·5	35	21	28·5
Ashton and Co., Wakamarino	Hard with sheelite ..	320	3 3 0	1 2 16	2 0 8	4 14 8	„	„	0 7 18	..	..	..	64	95	65·4	64	95	65·4
Sanderson Bros., Okupu Bay, Great Barrier Island	Friable quartz ..	2,030	89 14 15	0 10 2	89 4 13	13 3 3	„	„	63 0 0	..	..	..	86	72·2	72·3	86	72·2	72·3
Mr. T. R. Williams, Russell	Brecciated quartz ..	320	5 17 11	0 5 1	5 12 10	1 16 6	„	„	0 16 0	..	..	..	87	86	86·5	87	86	86·5
Mr. B. Wolff, Wakamarino	Hard crystalline quartz	2,240	3 2 2	0 13 8	2 9 12	2 16 0	„	„	2 10 0	..	..	..	85	87·7	83·8	85	87·7	83·8
Sanderson Bros., Great Barrier	Friable quartz ..	2,240	268 1 9	0 7 13	267 13 20	28 5 6	„	„	161 6 0	..	..	..	91	60	60·2	91	60	60·2
Mr. S. James, "Success," Coromandel	Clean quartz ..	850	46 6 9	16 17 2	29 9 7	70 7 4	„	„	13 15 0	..	..	..	94	60	93·9	94	60	93·9

TABLE SHOWING FINENESS AND VALUE OF BULLION EXTRACTED FROM ORES.

No.	Name.	Fineness.		Value per Ounce.
		Gold.	Silver.	
				£ s. d.
1	Ocean View, Matarangi	·4500	·3795	1 17 0
2	Corbett, Marototo	·0540	·9290	0 7 0
3	McNeill, Matarangi	·6350	·3300	2 11 9
4	Kapai, Kuaotunu	·6354	·2250	2 11 6
5	McLiver, Puriri	·6360	·3431	2 11 9
6	Koputauaki	·0652	·8934	0 7 5
7	,, ...	·0650	·8938	0 7 4
8	Ashton, Wakamarino	·2674	·7112	1 99
9	Sanderson, Great Barrier	·0062	·9201	0 2 9
10	Williams, Russell	·0388	·8844	0 4 10
11	Wolff, Wakamarino	·2173	·7262	0 19 2
12	Sanderson, Okupu Bay, Great Barrier Island ...	·0022	·9726	0 2 4
13	James, " Success," Coromandel	·4700	·5196	1 18 7
13A	,, ,, (specimens)	·7132	·2856	2 17 7

The ores from Matarangi, Kuaotunu, and Puriri were free from metallic sulphides, and well suited for treatment by the Cassel process, especially in conjunction with dry-crushing.

The ore from Marototo, forwarded by Mr. Corbett, contains a large proportion of its bullion in the form of a telluride of silver, which is not an amalgamable ore, hence the low extraction.

The parcels of ore from Koputauaki Bay, near Coromandel, forwarded by Mr. Montgomery Davis, contained a large proportion of iron- and copper-pyrites, zinc-blende, galena, and some grains of tetrahedrite, with which the silver seemed to be associated. The low extraction from these valuable ores show that they cannot be successfully treated by amalgamation.

The Wakamarino ores contained a small percentage of scheelite, which did not seem to injuriously affect the results by pan-amalgamation.

SYLLABUS OF LECTURES AND INSTRUCTION FOR 1893-94.

Practical Assaying.—(Lecturer and Instructor, the Director, assisted by Mr. F. B. Allen, M.A., B.Sc.)

Dry Assaying.—(1.) The furnaces and appliances used in fire-assaying, with sketches. (2.) The fluxes, their properties and uses. (3.) The reducers and their reducing-powers. (4.) Fuels and other reagents, as salt, iron, sheet and granulated lead, glass-powder, &c. (5.) Preparation of pure silver for parting Au and Ag. (6.) Preparation of nitric-acid solutions for parting. (7.) Preliminary assays of ores and bullion—their use and application. (8.) Volatility of gold and silver; the influence of different temperatures in different parts of the muffle, and of time in the muffle. (9). The operations in fire-assaying—*a*, powdering the ore; *b*, sampling the dry pulp; *c*, preparing the charge; *d*, fusing the charge and extracting the lead button; *e*, cupelling the lead button; *f*, weighing the bullion; *g*, parting and calculating the value of the bullion. (10.) Probable sources of error in fire-assaying. (11.) Keeping note-books and proper records of results. (12.) The assay of litharge and red-lead. (13.) The assay of gold and silver and their ores—*a*, in clean quartz; *b*, in pyritous quartz; *c*, in concentrates and tailings; *d*, in roasted ores; *e*, by amalgamation assay; *f*, by scorification assay. (14.) The retorting and melting of bullion. (15.) The refining of base bullion. (16.) The assay of bullion—*a*, weighing the assay; *b*, cupelling for base; *c*, adding pure silver for parting; *d*, rolling the cornet; *e*, parting the cornet; *f*, calculating the value. (17.) The calculation of results obtained in batteries from treatment of gold- and silver-ores. (18.) The assay of galena and cerussite—the valuation of lead, gold, and silver. (19.) The valuation of lead-bullion. (20.) The assay of tin-ore (cassiterite).

Wet Assaying.—(21.) Operations—*a*, solution; *b*, crystallization; *c*, precipitation; *d*, filtration; *e*, decantation; *f*, washing; *g*, evaporation; *h*, distillation; *i*, ignition; *j*, sublimation; *k*, fusion; *l*, use of blowpipe; *m*, the use of spirit- and gas-lamps; *n*, the preparation of reagents, and tests of purity, &c.; *o*, the preparation of fluxes; *p*, test-papers; *q*, the balance, weights, operations of weighing; *r*, preservation of platinum crucibles. (22.) The assay of iron-ores—*a*, gravimetric; *b*, volumetric. (23.) The assay of copper-ores—*a*, as oxide; *b*, as metal by electrolysis; *c*, volumetric; *d*, colorimetric. (24.) The assay of antimonite. (25.) The assay of bismuth glance. (26.) The assay of cinnabar. (27.) The assay of galena. (28.) The assay of zinc-ores. (29.) The assay of manganese-ores. (30.) The assay of nickel-ores. (31.) The assay of cobalt-ores. (32.) The assay of chromite of iron. (33.) The assay of arsenic ores. (34.) The assay of silver-ores—*a*, volumetric; *b*, gravimetric. (35.) The valuation of specimens.

Metallurgy of Gold and Silver.—(Lecturer, the Director.)

(1.) Ore-crushing and -pulverizing machinery—*a*, rock-breakers; *b*, stamps; *c*, mills, rolls, &c. (2.) Metallurgy of gold—*a*, amalgamation on copper plates, in pans, &c.; *b*, chlorination processes and operations; *c*, leaching processes (Cassel's, &c.). (3.) Metallurgy of silver—*a*, smelting and amalgamating ores; *b*, smelting—reduction with lead and fluxes; *c*, amalgamation in pans with mercury—use of chemicals; *d*, leaching with solvents—sea-water or brine, ammonia, sodium hyposulphite, alkaline cyanides; *e*, oxidizing and chloridizing roasting.

Practical Chemistry.—(Lecturer and Instructor, Mr. F. B. Allen, M.A., B.Sc.)

Junior Class.—(1.) Operations (these are the same as for wet assaying). (2.) The separation of the metals into groups. (3.) Qualitative tests for the different metals. (4.) The separation of silver, lead, mercury. (5.) The separation of copper, bismuth, arsenic, and antimony. (6.) The separation of iron and alumina, iron and zinc, iron and manganese, iron and chromium. (7.) The separation of calcium and magnesium. (8.) The separation of barium, strontium, and calcium (9.) The separation of potassium and sodium. (10.) Qualitative tests for the acid-radicals (inorganic)—*a*, H_2S, HCl, HBr, HI; *b*, HNO_3, $HClO_3$; *c*, HBO_2, H_2CO_3, H_2CrO_4, HF, H_3PO_4, H_4SiO_4, H_2SO_4, H_3AsO_4.

(Lecturer and Instructor, the Director.)

Senior Class.—(1.) The estimation of chlorine. (2.) The estimation of sulphuric acid and sulphur. (3.) The estimation of phosphoric acid. (4.) The analysis of limestones and calcareous freestone. (5.) The analysis of coals, coke, charcoal, and shales. (6.) The analysis of barytes. (7.) The analysis of fluor-spar. (8.) The analysis of scheelite and wolfram. (9.) The analysis of rocks (including estimation of K_2O and Na_2O). (10.) The analysis of fireclays. (11.) The analysis of soils. (12.) The analysis of complex sulphide ores. (13.) The analysis of milk. (14.) The analysis of waters. (15.) The analysis of bone-dust and bone-ash, with estimation of nitrogen. (16.) The analysis of guanos and apatite. (17.) The analysis of superphosphates. (18.) The estimation of alcohol—*a*, by weight; *b*, by volume. (19.) Volumetric analysis: The estimation of—alkaline hydrates; alkaline carbonates; acids, HCl, H_2SO_4, HNO_3, $HC_2H_3O_2$, $H_2C_4H_4O_6$; haloid salts, HCN, KCN, I, As_2O_3, SO_2 ($Na_2S_2O_35H_2O$).

Theoretical Chemistry.—(Lecturer, Mr. F. B. Allen, M.A., B.Sc.)

Principles of Chemistry and Chemical Philosophy.—Atoms, molecules, vapour-density, quantivalence, chemical formulæ.

The Elements.—(1.) Their history, occurrence, preparation, properties, uses. (2.) Compounds of the elements, their history, preparation, properties, uses, &c.

Mathematics.—(Lecturer and Instructor, Mr. F. B. Allen, M.A., B.Sc.)

Arithmetic (including the simple rules).—Weights and measures (those bearing on mining and assaying), greatest common measure, least common multiple, vulgar fractions, decimal fractions, proportion, problems.

Algebra (Hall and Knight's Algebra).—The meaning and use of the various signs and symbols, the simple rules, greatest common measure, least common multiple, fractions, factors, symmetry, problems containing one unknown, simultaneous equations, quadratic equations, simultaneous equations with more than one unknown, problems involving quadratics and the use of several unknowns, practice in the use of formulæ and their transposition.

Euclid.—The first four books (Todhunter), including the definitions and axioms.

Mineralogy and Blowpipe Determination.—(Lecturer and Instructor, the Director.)

Systematic Mineralogy.—(1.) Physical properties of minerals, their hardness, S.G., &c. (2.) Optical properties—refraction, reflection, polarisation, lustre, phosphorescence. (3.) Chemical properties. (4.) The application of the blowpipe, colour-tests, &c. (5.) Isomorphism, pseudomorphism, and allotropy. (6.) Distribution and paragenesis of minerals. (7.) Classification of minerals—chemical, economic.

Descriptive Mineralogy.—(1.) Non-metallic division—carbon group, &c. (2.) Metallic division—a description of the principal ores of the common metals, and their New Zealand localities and modes of occurrence.

Crystallography.—(1.) The six systems, their cells, typical forms, modified forms, &c. (2.) Holohedral and hemihedral forms. (3.) Reading of faces.

The general syllabus of instruction is the same as that mentioned in my report for the previous year.

Scale of Charges for Public Assays and Analyses.

		£	s.	d.
Analysis of limestone and calcareous freestone	complete	1	0	0
	partial	0	10	0
" coals and fuels, each		0	10	0
" rocks and soils	complete	2	0	0
	partial	1	0	0
" fireclays and slags		1	0	0
" manures		2	0	0
" waters	complete	3	0	0
	partial	2	0	0
" nickel-, cobalt-, and chrome-ores		0	10	0
" concentrates		1	10	0
" complex sulphide ores, &c.		1	10	0

Class-fees.

Registration or membership for a year, 10s.; all class-fees 5s. per quarter for each subject.

Students are supplied with crucibles, glassware, apparatus, chemicals, &c., free of charge, but they must make good all breakages.

Experimental Plant.

Parcels of gold- and silver-bearing ores, up to three tons, are treated exhaustively, and reported on, from £3 to £5 per ton or part of a ton, according to the nature of treatment required. All ex-

penses connected with the treatment are paid by the school, and the bullion extracted is returned to the owner.

Terms.

The period of instruction extends over three long terms in the year, instead of four short terms of the same duration, as kept by the public schools and High School. First term, 1st February to 30th April; second term, 15th May to 15th August; third term, 1st September to 30th November. Annual examinations, 1st to 15th December.

Lectures.

Two public lectures were delivered last year at the School of Mines—one by Sir James Hector, F.R.S., Chancellor of the New Zealand University, on "The Geology of the Thames Goldfield," and the other by Mr. H. G. Pitcairn, representative of the Luhrig Ore-dressing Company, on "The Principles of Concentration." Both lectures were of a very interesting and instructive character, and were listened to by large audiences.

Annual Distribution of Certificates.

The annual distribution of prizes and certificates took place on the 2nd February. There was a large attendance of the public and of students. Among those present were Mr. R. Murray, F.G.S., Geologist for Victoria, Mr. Henry A. Gordon, C.E., F.G.S., and Mr. A. McKay, F.G.S., Mining Geologist. The prizes and certificates were distributed by the President, Mr. J. McGowan, M.H.R., and at the conclusion of the ceremony the Director and Mr. Gordon addressed the meeting. Mr. Gordon, in a very able and thoughtful speech, pointed out the advantages and necessity of a technical knowledge to all those engaged in mining and milling pursuits. He spoke in highly appreciative terms of the work being done by the school, and said it was a pleasure to him to hear of the successes of our certificated students.

Governing Body.

At the annual meeting, the following officers and Committee were elected for the current year: President, Mr. J. McGowan, M.H.R.; vice-presidents, Messrs. T. A. Dunlop and G. Bull; members, Messrs. G. S. Clark, J. H. Smith, W. Baker, P. C. Hansen, J. Brown, J. H. Whittaker; treasurer, Mr. J. Watson; secretary, Mr. A. Bruce.

In conclusion, the Committee have at all times afforded me their hearty support and co-operation in all matters pertaining to the welfare of the school, and the different mine-managers on this and other fields in the Hauraki Peninsula have at all times given myself and students ready access to their mines to conduct underground surveys and examinations. It affords me great pleasure also to acknowledge the valuable and willing help received from my assistant, Mr F. B. Allen, M.A., B.Sc.

REEFTON SCHOOL OF MINES.

There has been a considerable falling-off in the attendance at this school last year, which Mr. Aitken, the Director, attributes to the repeated breaking-up of the classes, occasioned by his visiting the smaller schools on the West Coast, which, he admits, are of no practical value to those who attend them. The remarks of Mr. Aitken in reference to this are well founded, for it is well known that, unless the work is carried on continuously for a certain term, the teaching is, in a manner, wasted. If regular instruction were given, there would be a far greater chance of getting a large attendance: people would come from other places to attend the school, as they do at the Thames, and some good would result from the teaching. Itinerant teaching is only good to cause the miners to direct their attention to the necessity of becoming better acquainted with the chemistry of metals, and to enable them to distinguish the mineral ores when they meet with them, but a few lectures now and again are not of any practical value.

During last year Mr. Aitken held classes at Boatman's, "The Progress," Brunnerton, Kumara, Stafford, and Hokitika, and also spent about two weeks examining and testing the ores in the vicinity of Mount Rangitoto, where gold and silver was reported to be found in a granitoid formation; but, after making a large number of tests, he did not find any ore which he deemed payable for working. There is a little gold in a belt of country which is composed of gneissic granite, which in many places has a distinct schistose structure, having veins of felsite through it in places. An adit was driven for about 40ft. into this formation, and from this adit a number of samples were tested. On one side of the gneiss formation there is a belt of altered slate, into which the veins of felsite run for some distance. A good deal of prospecting has been done on this belt. Two adits have been driven for some distance, following small veins of iron-pyrites, galena, and zinc-blende. Another adit has been driven at the junction of the slate and gneiss for 400ft., and samples were taken from it and tested, but none of the results came up to expectations. There is, however, no saying where payable ore may be found in this locality, gold having been found—although in small quantities—in this formation.

Two assays have been made during the year from tailings from the Globe, Progress, Welcome, Scotia, Sir Francis Drake, and Cumberland Companies' batteries, with the result that the minimum quantity of gold obtained was 2dwt. 6gr., and the maximum 13dwt. 1gr., per ton. There is said to be about 44,400 tons of tailings at these crushing-batteries. Taking the average of the assays, these tailings contain 5dwt. 21·7gr. of gold per ton, which gives a total value of £52,445. Of this amount the Globe Company has tailings having a value of £27,480; the Progress, £1,812; the Welcome, £10,950; Scotia, £1,043; Sir Francis Drake, £2,100; and the Cumberland Company, £9,060. If even 75 per cent. of this value were extracted, it shows that there is gold to the value of £39,334 that ought to be obtained with ordinary care.

The following is the report of Mr. R. Aitken, the Director of the Reefton School of Mines, showing the progress made during the year ended the 31st March, 1894:—

I have the honour to furnish my report on the work and progress of the Reefton School of Mines and its branches for the past year ended the 31st March, 1894, which, I regret to say, is not so successful as that of the previous year.

There has been a decrease in the number of students attending the various classes, which is, no doubt, to some extent, due to the depressed state of the district. The work shown by the students at the last annual examinations was by no means good, as many of the students refused to compete, owing to the irregularity of the classes, and especially as I was absent from Reefton a month, just before the examinations were held.

This falling-off in the attendance and efficiency of the Reefton school and its branches is due, to a large extent, to the repeated breaking-up of the classes, occasioned by my visiting the smaller schools further down the coast.

These short visits, which are of no practical value to the students, have seriously interfered with the Reefton school, which last year showed that good, sound, and practical work was being done. The efficiency of this school can never be maintained unless the classes are carried on for at least nine months during the year without interruption. A month's instruction could then be given to two or three of the other schools, which would, no doubt, be of some value in keeping them together.

There are many persons who are desirous of joining the classes and attending if regular instruction could be given.

The following table shows the attendance at the different classes and schools during the past year:—

Name of Class and School.	First Term.	Second Term.
Reefton, Assaying and metallurgy	12	8
" Practical chemistry	9	6
" Theoretical chemistry	9	6
" Geology and mineralogy	5	...
" Land- and mine-surveying	13	9
" Mining and mathematics	14	9
Boatman's, Chemistry	4	...
Progress, Mining and surveying	8	...
Brunnerton, Mining and surveying	12	5
		Average.
Hokitika class		12
Stafford, Lectures		20
Kumara, "		6

Practical Assaying and Metallurgy.—In this class the students are instructed in assaying of all metals by the wet and dry methods, and in the composition of fluxes, fuels, reagents, &c.; together with the smelting, valuing, and refining of gold and silver bullion, the dressing and curing of copper plates, amalgamation, and retorting. Instruction is also given in methods for the extraction of gold and silver from their ores, such as battery-work, stampers, boxes, screens, plates, and ripples; also in the methods of amalgamation and concentration.

A large number of assays have been made during the year in this class, and most of the assays are large, nothing under 1,000-grain assays being made for tailings yielding from 5dwt. to 15dwt. per ton, and for sand under 5dwt. from 1,500-grain to 2,000-grain assays are made. This is done to give weighable beads of gold, and more correct results, for with poor sand it is difficult to obtain correct results by making 400- and 500-grain assays. The students attending this class have made good headway, most of them being new members at the school.

Practical Chemistry.—This class was fairly well attended during the year by students attending the assaying and metallurgy classes, as this subject is practically the basis of wet assaying. Instruction is given in the preparation of reagents and salts, testing for acids and metals, separation and detection of metals and mineral substances, besides assays and analysis by gravimetric and volumetric methods. In this class, a large number of samples of tailings, &c., were treated by the cyanide process for the extraction of gold and silver, and samples of concentrates by roasting and chlorination, the students being instructed in the working of these processes.

Theoretical Chemistry.—This class has been held in conjunction with that of practical chemistry. The work has been confined principally to the non-metallic elements, their properties and uses being illustrated by various experiments. Instruction is also given on atoms, molecules, quantivalence, specific gravity, formulæ, and the properties of gases, solids, and liquids. The text book used in both practical and theoretical chemistry is "Bloxam."

Geology and Mineralogy.—A class in these subjects was started at the beginning of the year with about five students. The work done was confined to the determination of rocks and minerals by the aid of the blowpipe. After about two months' work the classes had to be discontinued.

Mining and Mathematics.—This class, which has been for some time attended better and more regularly than any of the other classes, has this year fallen back very much, and towards the end of the year was only attended by those who wished to qualify themselves for certificates under "The Mines Act, 1891." Instruction is given in logarithms; plane trigonometry; mining geology; strength of material, timbering; formation of lodes, leads, and veins; pumping and pit-work, pipes; hauling and winding, engines, boilers, horse-power; ventilation furnaces, fans, splitting of air, and gases; friction; explosives; water-power, water-races, motors, and measurement of water; arithmetic formulæ, &c. Special classes had also to be held for those desirous of obtaining engine-drivers' certificates. The majority of students who attend these classes are miners, or those connected with mining operations.

In January, 1893, I sent six candidates up for examination under "The Mines Act, 1891." One under the Mining Act and one under the Coal-mines Act, both of whom passed first-class; together with four for engine-drivers, three passing and one failing. In all, from these classes during the last three years, twenty-two students have successfully passed the examinations, as follows: Twelve under the Mining Act, five under the Coal-mines Act, and five for engine-drivers. In January, 1894, I sent for examination eleven candidates—three for first-class mine-managers, three for first-class coal-mine managers, and five for first-class engine-drivers; the results of these are not yet known.

Land- and Mine-surveying.—The number attending this class shows a decrease on that of the previous year. Many of the older students have left the district, and have found that the knowledge obtained in this subject has been of great value to them in other parts. Instruction is given in the use and adjustments of the compass, dial, and theodolite; in the tabulation of traverses, calculating areas, heights, and distances, plotting by protractor and rectangular co-ordinates and levelling; also in the laying-out of roads and water-races.

Boatman's.—A class was started here in chemistry, and continued for a short time, but the attendance became so small I found it necessary to close the school.

Progress.—This class was continued on until the Progress and Globe Companies found it necessary to discharge men; this considerably lessened the number attending the school, and, what with the frequent interruptions to the classes, this school had to be closed.

Brunnerton.—This place I visited twice during the year, holding classes in mining and surveying; but, owing to many of the miners being compelled to leave the district, a falling-off took place in the average attendance. Some very good work was done at this school, many of the students making rapid headway; and, although classes are not being held at present, some have obtained enough information to continue on by themselves.

According to instructions, I visited Hokitika, Kumara, Greymouth, and Brunnerton. At Greymouth no school of mines could be found, it being now formed into a library. I therefore held a few classes at Stafford instead. These places were visited twice during the year—once in May, and again in November; but very little work of any practical value was done, excepting at Brunnerton.

At Hokitika the average attendance would be about twelve to sixteen, partly females, who do not come to learn chemistry or assaying, but to see experiments. Mr. Purkiss, who takes a very great interest in the school, informed me that he held a junior chemistry class for boys during the winter months, which had been very well attended.

The school is fairly well stocked with chemicals and apparatus, including a very compact fusion and cupelling furnace; but lately a camera has been obtained, and the adult class has taken up photography as a subject.

At Stafford three or four classes were held, with a very good attendance of about twenty. There are a few at this school who take a great interest in the assaying and chemistry; but the majority of those who attended came simply to see the experiments, and as soon as work of some practical value was commenced the attendance was much smaller.

At Kumara, on my first visit, six or eight attended, and took some interest in the work, when some testing, chemistry, and assaying was gone through. On my second visit, however, the school seemed to have broken up, and I failed to get any classes together.

Merrijigs.—At this school the classes had been conducted by Mr. B. Southerland, but he discontinued on account of the few attending. There is, however, every prospect of a good school being commenced there this year, as a great many miners have now settled in this district, and a State school has been built, the use of which can be had for school-of-mines purposes. The school is a central place for a great many of the mines in that locality.

Recfton School.—There has been but little done this year in the way of adding improvements to the school, as, owing to a falling-off in the number of subscribers, it has taken most of the funds to keep up the supply of chemicals, apparatus, fuel, &c. The fee for membership has now been reduced from £1 to 10s. per annum, and 5s. per term is being charged to students for each class. This small fee of 10s. will no doubt induce many to become members of the school who do not wish to attend the classes. The school is still badly lighted, which is very inconvenient to students when many are working together, and as all work is done at night it is a serious drawback to the school.

It is intended, should funds permit, this year to start and erect a small testing and experimental plant in connection with the school, which would prove a valuable addition, and would no doubt do some good for the district. Most of the stone in this district carries more or less gold-bearing pyrites, which are simply berdaned and allowed to run away. By the aid of a small roasting-furnace and amalgamating-pans, or chlorinating-vats, practical tests could be made to prove these concentrates payable or otherwise. Large parcels from the various heaps of tailings could also be experimented on by different processes, when more practical working-results would be obtained.

The Laboratory.—During the past year about 223 assays, cyanide tests, berdan tests, &c., have been made, independent of numerous experiments, determinations of minerals, &c., which shows a considerable increase over that of the previous year. They are made up as follows: Fire-assays, 120; cyanide tests, 60; coal analysis, 4; analysis, 3; berdan amalgamation tests, 20; assays and tests for platinum, 9; meltings of bullion, 5; bullion assays, 2; besides cleaning and curing about 25 copper plates.

Most of the berdan tests were made on new finds of stone about the district, some of which gave very fair returns, but the majority were poor. Some of the assays for platinum were made on samples from the boxes of an alluvial claim on the Inangahua River, but in none of the sand could traces of platinum be found. One peculiar thing about some of the gold in this claim was that,

although no mercury was being used, the gold was coloured white, resuming its yellow colour on heating. I did not receive a sample of the gold, but this colouration may be due to the presence of bismuth.

Many assays and tests by cyanide have been made on the tailings and concentrates about the district, and on the cements which extend along the coast. The results of a few of these may prove of some interest. Small samples of concentrates have also been tested by roasting and amalgamation, also some by chlorination, and very good extractions have been obtained. The tests were, however, small, and would no doubt be of some practical value if performed on a large scale.

TABLE SHOWING ASSAYS AND QUANTITY OF TAILINGS.

Tailings.	Fire-assay per Ton. Gold.	Quantity in Tons.
	Dwt. gr.	
Globe	4 14	About 30,000 tons.
Progress	6 1	Lately started to save their tailings; about 1,500 tons.
Welcome	9 3	About 6,000 tons.
Scotia	13 1	" 400 "
Drake	2 6	" 2,000 "
Cumberland, lying at Drake Battery ...	5 10	" 1,500 "
" lying at Cumberland Battery ...	12 10	" 3,000 "

	Gold. Oz. dwt. gr.
Cumberland, blanketings	2 8 0 per ton.
" berdan tailings	1 9 3 "
Progress, blanketings	2 9 8 "
" buddlings	0 13 1 "
Globe, blanketings	1 13 5 "
Burke's Creek, tailings	0 7 20 "
Alpine, tailings	0 7 4 "
Brown's Terrace, cement	0 3 0 "
Charleston, cement	0 1 23 "

CYANIDE TESTS.

Material.	Method.	Time.	Consumption of Cyanide.	Extraction.
Progress, tailings	Percolation	30 hours	0·19 per cent.	75 per cent.
Alpine, "	"	30 "	0·2 "	70 "
Welcome, "	"	50 "	0·25 "	68 "
" "	Agitation	20 "	0·17 "	88 "
Scotia, "	Percolation	48 "	0·18 "	85 "
Rich sample of cement	Agitation	20 "	0·13 "	97 "

In making tests with cyanide by percolation, the solutions were percolated alternately upward and downward, which I consider is better than the downward percolation only, and where the ore is slimy the slow upward percolation carries the slimes towards the surface, and allows the downward percolation to proceed without choking the filter-bed with slimes. In some of my experiments when working by agitation free oxygen gas was added, which in some cases gives much better and quicker extractions, without a further consumption of cyanide. Tests made on the decomposition of cyanide show that pure oxygen gas has little or no effect on the solutions, for, after passing a constant current of the gas for some time through solutions of different strengths, the strengths of the solutions remained unaltered; but, on passing a current of pure washed carbon dioxide or carbonic acid, CO_2, through the same solutions a rapid decomposition takes place, forming carbonate of potash. This shows that the decomposition of cyanide of potassium is partly due to the absorption of atmospheric carbonic acid by the solutions.

The cyanide plant erected last year for the purpose of treating the Boatman's tailings has so far turned out a failure. The first trial made showed a very poor extraction with a high consumption of cyanide, the time given to each tank being too short—*i.e.*, twenty-four hours. Two other trials have since been made, and very fair extractions obtained; but, owing to the mode of working, and the time given to each tank, the gold obtained does very little more than pay the expenses of working and cyanide. There is no doubt that on this field a large percentage of the gold is lost in the floured or sickened mercury, besides what escapes as free gold, especially from batteries where amalgamation is performed in the stamper-boxes. From most of the tailings a prospect of floured mercury may be obtained by concentration, and, as cyanide acts very slowly on mercury, longer percolation is no doubt required in some cases in order to extract the gold.

Annual Examinations.—The usual annual examinations for students were held in December, 1893, when very few of the students competed. In these examinations the students of this school have not the same chance as those of the Thames School, where classes are carried on regularly, and it is for this reason that so few attempted the papers at the last examinations.

In conclusion, I must thank the Committee for the valuable assistance they have always given, and also those members who have given their services in keeping the classes together, and worked in the interests of the school.

OTAGO SCHOOL OF MINES.

This school is attached to the University of Dunedin, and is doing good work. Last year nineteen students attended the course of lectures, and out of those who came up for examination there were only three failures—one in mathematics, one in theoretical mechanics, and one in petrography. It will be seen from Professor Ulrich's report to the Chancellor of the University of Otago, on the progress made at the school last year, that many of the students have previously taken high degrees at the University, and ought therefore to be well qualified to readily acquire a knowledge of the subjects taught at the School of Mines. The students at this school have the advantage of being taught in subjects relating to mining by a professor who has not only acquired a theoretical knowledge, but also has been working in the mines, where he gained practical experience. He is also acknowledged to be one of the best mineralogists in the Australasian Colonies. The students are, however, only engaged in their studies for about half the time that those are who attend the Thames School of Mines. The offer by the Hon. the Minister of Mines of three scholarships, tenable for three years, at the Otago University, will enable a comparison to be made of the advantage of early teaching at this school with those attending the Thames and Reefton Schools of Mines.

The Director, Professor George H. F. Ulrich, reports on the progress made by the Otago School of Mines as follows:—

I have the honour to submit the following report on the work and the results of the School of Mines during the past session (1893):—

In my report of last year I intimated that, in addition to the seven students who had completed their studies, the school would lose five who did not intend to proceed. As it turned out this latter number was increased to seven, so that only eight of the old students remained. I am, however, glad to state that eleven new students entered, so that during the past session the school counted nineteen students, who, save two, attended lectures with great regularity —the two having through illness been prevented from attendance for some weeks, and being the only ones who failed in the examinations in some of the subjects.

Of these nineteen students, three entered for special subjects only—namely, one for general geology, one for advanced assaying, and one for mineralogy and petrography; the remaining sixteen being regular registered students, whose present status is as follows:—

Seven of the new students passed through the first year's course of the mining division. One new student for the mining division, who is also studying for the B.A. degree, took what lectures suited his time, and may be said to have passed through the first year's course. Two students, who entered for last year's session with the intention of devoting four years to passing through the three-years course, have passed most subjects of the second year's course. Two students of three years' standing, who would have finished their studies for the mining division, are those who, as before mentioned, became ill during the session, and having failed in some of the subjects will have to come up again for examination next year. One student of three years' standing, who is qualifying for the B.Sc. degree, passed in most of the subjects of the mining and metallurgical divisions, and will require another year to finish.

Of three remaining students, one, Donald J. Matheson, B.A., who gained his degree during the session, passed examinations in most of the subjects of the mining and metallurgical divisions, and would complete his studies by attending another session, but I am uncertain of his return.

John Chisholm, B.Sc., who gained, during the past year, his degree and a senior scholarship in physical science, passed in the remaining subjects of the mining, metallurgical, and geological divisions, and was granted the diplomas of associateship of the metallurgical and geological divisions. On producing satisfactory evidence of having gone through a twelve-months course of practical work in mines, he will also be entitled to the diploma of associateship of the mining division. It deserves mention that in the recent examinations in the six subjects which completed his mining course he passed first-class in five and good-second-class in one, whilst he also obtained a first-class in advanced physics, in which science he is preparing for honours.

Percy G. Morgan, M.A., after two years' engagement in practical mine-work, attended lectures and passed the examinations in several subjects required to complete the third year's course of the mining division, and was granted the diploma of associateship of this division.

With regard to past students I have to state the following:—

P. Fitzgerald, who left the school last year, after passing examinations in all the subjects of the mining division, but who had not at that time completed the twelve-months course of practical mine-work, did since submit satisfactory certificates of having fulfilled this requirement, and became therefore entitled and was granted the diploma of associateship of the mining division.

C. McKeller, who left the school last year, after passing examinations in all the subjects prescribed for the surveying division, produced the required evidence of having, for six months, been engaged in practical surveying work, and was therefore granted the certificate of the surveying division.

P. Marshall, M.A., B.Sc., who, during his last year's attendance at the school, and with the intention of qualifying for honours in geology, specially studied mineralogy and petrography, and prepared a paper on a geological subject, was awarded first-class honours by the English examiner.

The attendance of the classes, and the results of the annual examinations, are shown in the following table:—

Subjects.	Attendance.	Entered for Examination.	Results of Examination.			
			1st Class.	2nd Class.	3rd Class.	Failures.
General (University)—						
Mathematics	7	6	...	2	3	1
Theoretical mechanics	4	4	...	...	3	1
Theoretical physics	2	2	...	1	1	...
Practical physics	3	3	...	..	3	..
Theoretical chemistry	9	9	1	6	2	...
Practical chemistry	9	9	4	5	...	...
Special (School of Mines)—						
Mining, second course	9	9	1	6	2	...
Mining geology	9	9	1	7	1	...
General geology	9	8	1	5	2	...
Mineralogy	5	2	1	...	1	...
Petrography	6	5	...	2	2	1
Palæontology	1	1	1	...	...	...
Metallurgy, second course ...	4	4	2	...	2	...
Assaying, first course	5	5	2	3	...	...
Assaying, second course ...	1	1	1	...	...	...
Surveying, first course	3	3	1	2	...	...
Applied mechanics	2	2	2	...	...	...
Drawing, first year	6	6	3	3	...	...
Drawing, second year	3	3	2	1	...	...

The number of students remaining for next year's session is uncertain, as several of the old students, who finished their studies for the associateship of the mining division, were, at the close of the session, still undecided whether they would return for further study in any of the other divisions. It will probably be twelve; and, as the accession of several new students has already been notified, it is not unlikely that the standard of attendance of the past session will again be reached.

Regarding evening classes in assaying and surveying, the respective lecturers, Mr. Wilkinson and Mr. Begg, were prepared for students wishing to take advantage of this provision, but only one student entered for the class in assaying.

Shortly after the end of last session, the Deputy Inspector of the Seacliff Lunatic Asylum, Mr. F. R. Chapman, communicated to me that he would be very glad if any of our students who had gone through the surveying course would make a special survey of the asylum grounds, showing buildings, garden, bush, &c., as this would be of great use to the management of the institution. Provision would be made for the camping of the survey party and free railway-passes. The advantage to the students of gaining by the proposed work a good deal of practical surveying experience was so obvious that I directly communicated with Mr. Begg, and some of the students qualified for the work. Mr. Begg at once took the matter energetically in hand, formed a party of some five or six of the students, initiated the survey on the asylum grounds, and under his occasional supervision, and with the valuable assistance of Mr. Adams, Chief Government Surveyor, regarding the loan of necessary instruments, the survey was executed and the required plan prepared and handed to Mr. Chapman. As a letter from this gentleman (which I submitted to the Council) has since proved, the work—according to the opinion of experts—has been carefully and well done, reflecting great credit upon the students concerned and the teaching of Mr. Begg.

The work done for the public during the year, *i.e.*, since the close of session 1892, in assays and determinations of minerals by the lecturer in assaying, Mr. D. Wilkinson; by two associates of the school, Mr. Walcott and Mr. Waters, during Mr. Wilkinson's absence from the colony; and by myself, was as follows:—

Charged for at Fixed Rates.

(Work done by Messrs. Walcott and Waters.)

November 3rd.—Extraction of silver from photographic residues; for Mr. J. Thompson, Dunedin.

November 8th.—Examination and assay of gold-amalgam; for Mr. Proctor, Dunedin.

November 9th.—Assay of concentrates from quartz-crushing for gold; for Mr. Donald Reid, jun., Dunedin.

November 22nd.—Assay of pyrites for gold; for Mr. H. Morris, Dunedin.

November 22nd.—Two samples of pyrites assayed for gold: for Mr. Proctor, Dunedin.

November 23rd.—Assay of a sample of pyrites for gold; for Mr. J. C. Smith, Dunedin.

December 16th.—Sample of beach sand assayed for gold; for Mr. J. C. Smith, Dunedin.

December 22nd.—Sample of beach sand assayed for gold; for Mr. Cutten, Dunedin.

January 11th.—Sample of pyrites assayed for gold; for Mr. Donald Reid, jun., Dunedin.

January 18th.—Assay of sample of pyrites for gold; for Mr. J. P. Smith, Dunedin.

January 18th.—Assay of sample of black sand for gold; for Mr. J. P. Smith, Dunedin.

February 21st.—Reduction of silver from silver chloride; for Messrs. Souness and Gamble, Dunedin.

February 25th.—Two samples of concentrates from quartz-crushing, assayed for gold; for Mr. D. Reid, Dunedin.

March 6th.—Assay of concentrates from quartz-crushings for gold; for Mr. D. Reid, Dunedin.

March 6th.—Assays of two samples of quartz for gold; for Mr. Rapphaels and party, Dunedin.

March 20th.—Assays of two samples of quartz for gold; for Mr. Donald Reid, jun., Dunedin.

April 4th.—Assay of sample of quartz for gold; for Mr. Donald Reid, jun., Dunedin.

(Work done by Mr. Wilkinson.)

April 7th.—Complete analysis of scheelite; for Lammerlaw Antimony Mining Company.

April 26th.—Assay of sample of quartz for gold; for Mr. Donald Reid, jun., Dunedin.

April 28th.—Three assays of samples of quartz for gold; for Mr. W. E. Toase, Dunedin.

May 1st.—Assay of concentrates from quartz-crushing for gold; for Mr. D. Reid, Dunedin.

May 5th.—Estimation of silica in nine samples of crushed stone, to determine whether the powders were crushed flints, felspar, or Cornish stone; for Milton Pottery Works.

May 23rd.—Assays of two samples of pyrites—one from a white reef, the other from a red reef; for Mr. Toase, Dunedin.

June 19th.—Assays of two samples of quartz for gold; for Mr. J. P. Smith, Dunedin.

June 19th.—Assay of pyritiferous quartz for gold; for Mr. A. Maxwell, Dunedin.

June 19th.—Assay of sample of bluish-grey quartz for gold; for Mr. A. Maxwell, Dunedin.

June 23rd.—Three assays of samples of black ironsand, from dredges, for gold; for Mr. A. Maxwell, Dunedin.

July 12th.—Two assays of samples of quartz, from Wilson's River, West Coast, for gold; for Mr. E. W. Melland, Dunedin.

July 18th.—Two assays of samples of quartz, from Barewood, for gold; for Messrs. Donald Reid and Co., Dunedin.

July 24th.—Five assays of five samples of tin-ore concentrates for tin; for Rex Hill Mining Company, Tasmania.

July 27th.—Assay, for gold, of a sample of Barewood quartz; for Messrs. D. Reid and Co., Dunedin.

July 27th.—Assay, for gold, of concentrates and blanketings; for Messrs. D. Reid and Co., Dunedin.

August 5th.—Assay, for gold, of a sample of tailings; for Messrs. D. Reid and Co., Dunedin.

Not Charged For.

(Work done by Mr. Waters.)

December 28th.—Assay of a sample of quartz, for gold; for Mr. J. Allen, Dunedin.

December 29th.—Assay of a sample of pyrites, for gold; for Mr. J. Allen, Dunedin.

March 15th.—Assay of stream-tin; for Mr. Hooker, Dunedin.

(Work done by Mr. Wilkinson.)

April 13th.—Assay of sample of quartz, for gold; for Mr. C. McQueen, Dunedin.

April 13th.—Assay of tin-ore; for Mr. C. McQueen, Dunedin.

May 20th.—Determination of ash in carbonaceous clay; for Mr. McAdam, Dunedin.

July 13th.—Determination of coking properties and ash of a sample of coal; for Mr. Melland, Dunedin.

Determination of Rock and Mineral Specimens.

(Made by myself.)

A boulder found at Taukupu, Catlin's District, supposed to be a meteoric stone, proved on examination of thin sections under the microscope to be an aphanite-breccia.

Eight specimens of minerals and rocks, from the Raggedy Range, supposed to contain malachite and tin-ore, sent by the Hon. V. Pyke, proved to be simply ferruginous schist and sandstone.

Three specimens from Dusky Sound, supposed to be tin-ore, handed me by Captain Malcolm, proved to be pyrrhotite.

A sample of black sand, from Low Rocky Cape and head of Davey River, Tasmania, forwarded by Mr. Alfred Taylor, proved to be rutile.

A sample of a black mineral, found near Seacliff Lunatic Asylum, forwarded by editor of *Witness*, proved to be hornblende.

A specimen of a heavy white mineral, handed me by Dr. Hocken, proved to be scheelite.

A specimen of a dark rock, found at Gibbston, Kawarau River, forwarded by editor of *Witness*, proved on examination of thin sections under the microscope to be basalt, rich in olivine.

A metallic mineral, found in brown coal, near Gore, forwarded by editor of *Witness*, proved to be marcasite, or white iron-pyrites.

June 28th.—Mineral, found on a range near Dunedin, forwarded by editor of *Witness*, proved to be gypsum.

July 14th.—Mineral, forwarded by Andrew Donaldson, Beaumont, turned out to be a fine sample of cinnabar.

July 31st.—A sample of precious stones, found at Ngapara, forwarded by Mr. Robert Paulin, was found to contain zircon, sapphire, garnet, and obsidian.

August 15th.—Another sample of precious stones, from Ngapara, sent by Mr. Robert Paulin, proved to contain sapphire, green jasper, and agate.

August 23rd.—Red precious stones, from Ngapara, examined for Mr. Robert Paulin, proved to be zircons.

September 5th.—A white mineral, from Macquarrie Island, examined for Captain Malcolm, proved to be alabaster (gypsum).

September 22nd.—Two pebbles, supposed to be precious stones, forwarded by Mr. J. J. Henderson, Hokitika, proved to be—one bottle-glass, the other rock-crystal.

October 10th.—A specimen, forwarded by the Hon. V. Pyke, proved to be copper-pyrites, mixed with pyrrhotite, enclosed in a gneissose rock.

The teaching facilities and requisites for the geological classes of the school have, during the year, been materially enhanced and increased by several purchases made, with the Council's sanction, by Mr. D. Wilkinson on his late visit to England. Foremost, and acquired at a very low cost, is a large collection of excellent stratigraphical and palæontogical diagrams and pictures; next a small collection of fine specimens of fossil shells, &c., typical of geological formations; and recently there came to hand a little machine for the easy cutting of rock-sections, which will be of great use for the class in petrography.

In conclusion, I may mention that the rock and mineral collections of our mining museum have, during the year, been increased by the following presents:—

Mr. C. McQueen: A large sample of tin-ore, from Rex Hill, Avoca, Tasmania; four specimens of lode stone, from the Nugget Tin-mine, Ringarooma District, Tasmania; one specimen of pyritiferous gold-bearing quartz, from Holmes's and White's claims, Barewood.

Captain Malcolm: Three specimens of pyrrhotite, from Dusky Sound; and one specimen of tin-ore, associated with tourmaline, from Avoca, Tasmania.

The Hon. Vincent Pyke: Eight specimens of rocks, from Raggedy Range, Otago.

Mr. W. Goodlet: Fourteen specimens of minerals and rocks, from the West Coast of New Zealand; including two samples of stream-tin, from different localities; rhodonite; a number of crystals of magnetite; and several specimens of massive green margarite (matrix of Oriental ruby).

Mr. W. L. Neill: Three specimens of a granite, rich in microcline, from Santos, Brazil; and several specimens of crystallized pyrite and quartzite pebbles, containing gypsum and barite, from the neighbourhood of Gisborne, New Zealand.

Mr. G. R. Don: Several rock-specimens from Gympie, Queensland, and the North Island, New Zealand; and a druse of finely-crystallized quartz from the Waihi Mine, North Island, New Zealand.

All these new specimens have been labelled and arranged in the large glass cases, which, having now become rather crowded, offer little room for any additional specimens, so that the provision of a new glass case is very desirable.

MINOR SCHOOLS.

There are smaller schools of mines, where an instructor attends occasionally, and the advanced students and gentlemen who take an interest in technical education give instruction and lectures. The minor schools are situated at Nelson, Denniston, Brunnerton, Greymouth, Kumara, Waimea, Hokitika, Rimu, and Ross. The only reports received from these schools last year, showing the progress made, is from Hokitika, where Mr. W. M. Purkiss and Mr. Park have continued to give instruction. The former gentleman conducted the senior and junior classes in chemistry, and the latter held a photographic class. At Kumara Mr. Olden holds chemistry classes, and the Rev. Mr. Woodthorpe geological classes. Great interest is taken in the Denniston school by the miners, who wish to have instruction more regularly, so that many of them could have an opportunity to study the subjects required for a mine-manager's examination. At Rimu some of the advanced students give occasional instruction, but the school is used more for the purpose of analysing any mineral ores which the miners find in the locality.

The following is a report of the work done at the Hokitika school, which has been forwarded by Mr. T. H. Gill, the honorary secretary, on behalf of the Committee:—

Your Committee have very much pleasure in presenting the annual report of the School of Mines for the year just ended.

During the year the work of the school has been carried on in three departments—viz., the senior and the junior classes, and the photographic class. The two first have been conducted by Mr. Purkiss, and the last by Mr. Park. A few remarks under each of these heads are appended.

The work of the senior class was carried on throughout the winter months, and, although the attendance fluctuated from week to week, it was on the whole satisfactory. The metals of the first and second groups were treated exhaustively, and all the usual wet tests applied. The want of a suitable furnace has considerably diminished the usefulness of the school, but as this has now been secured and placed in position the work of the incoming year will be augmented by assaying, &c. This will no doubt be a benefit to the district in general, and this school in particular, as, with increased facilities for testing the various ores obtained, avenues of usefulness will be opened up.

During the year Mr. Aitken, Instructor of the Reefton School of Mines, visited the district; but as we were not in session his visit was almost resultless. If Mr. Aitken is to visit us periodically it is necessary that he should come when we are in session, and not during the vacation. The thanks of the school are due to Dr. Kendall for a very able and instructive lecture on "Poisons," which was illustrated by numberless experiments.

A feature of paramount importance was the work of the junior class, carried on from May to November. The chemistry rooms were crowded week after week, from 7 to 8 o'clock, by about eighty boys and girls, and the intelligent interest evinced during the course of the lectures, the subdued regret which mantled on the faces of the listeners when the lecture was over, and the very satisfactory examination they passed at the end of the course, augured well for the future of

the School of Mines. If the rudiments of chemical knowledge can be quietly instilled into the minds of the rising generation, and a love for the science implanted also, the prosperity of any school of mines is assured. It is to be hoped that the work so successfully initiated last year will be continued this year.

The third phase of doings of the school is the photographic class. Early in the year an entertainment was got up, and enough money obtained to purchase a camera and necessary appliances. Lectures were given in the chemistry rooms in the evenings, and practical work was done on Saturday afternoons and holidays, and already some of the class have shown considerable aptitude and ability in the art of photography.

EXPENDITURE ON SCHOOLS.

The following table shows the expenditure by the Government on Schools of Mines since their inauguration, exclusive of subsidies paid to the University of Otago towards the school of mines in connection with that institution :—

Financial Years.	Subsidies towards the Erection of Schools of Mines, and Maintenance.	Chemicals and Apparatus, also Mineralogical Specimens supplied to Schools of Mines.	Salaries of Teachers, and Travelling-expenses, &c.	Total Sums paid by the Department towards the Schools of Mines.
	£ s. d.	£ s. d	£ s. d.	£ s. d.
1885–86	...	36 19 9	1,223 9 10	1,260 9 7
1886–87	257 16 6	409 1 4	2,716 9 3	3,383 7 1
1887–88	253 15 9	253 14 1	1,714 9 6	2,221 19 4
1888–89	42 10 0	6 12 9	1,139 4 1	1,188 6 10
1889–90	142 2 0	181 14 10	716 3 10	1,040 0 8
1890–91	217 6 6	54 8 0	620 9 9	892 4 3
1891–92	181 14 0	...	689 5 9	870 19 9
1892–93	312 3 4	...	670 1 0	982 4 4
1893–94	197 0 5	...	858 19 4	1,055 19 9
Totals	1,604 8 6	942 10 9	10,348 12 4	12,895 11 7

In addition to the amount shown in the foregoing statement, £4,250 has been paid towards the maintenance of the school of mines attached to the Otago University, which makes the total expenditure on schools £17,145 11s. 7d. The total expenditure last year, including £500 paid to the Otago University, amounted to £1,555 19s. 9d. Those engaged in mining pursuits fully appreciate the advantages of a technical education at these institutions, and many avail themselves of the opportunity afforded of acquiring a theoretical knowledge of subjects connected with working of mines and treatment of ores, of which several of them have had many years' practical experience; and it is from such class of men that we may expect to find our future mine-managers. The time has gone by when everything was done by the rule-of-thumb. Mines are now worked to much greater depths than in former years, and ores which a few years ago were considered valueless are now worked at a profit. On all the principal goldfields there are now men who can test and ascertain the value of ores met with, and this can be justly attributed to the establishment of the schools of mines.

WATER-RACES.

Waimea Water-race.

On the upper portion of the Waimea Water-race there is about 70 chains of high fluming which is getting greatly decayed, it having been up for nearly twenty years. Breaks are taking place from time to time, which cost considerable sums to repair, and the boxing is getting into such a decayed condition that it will shortly have to be entirely replaced or done away with altogether. This fluming is about two miles above the long siphon, and, as this siphon is 3ft. in diameter, and has a fall of 81ft. between the intake and the outlet end, and its length 12,500ft., it would be sufficiently large to carry all the water required if the level of the upper end of the water-race was lowered 40ft. This would still give it a fall of 1 in 300, which would make its carrying-capacity about thirty-four sluice-heads. It is therefore proposed to construct a ditch at 40ft. lower level from the upper end of the siphon, and do away with most of the fluming. The cost of this will be less than replacing the fluming at its present height, and do away with expensive maintenance in the future. The manager has been instructed to make a survey of this deviation, so that a comparison can be made of the cost of the ditching as against the re-erection of the fluming.

The branch of this water-race has been constructed from the outlet end of the pipe-line or siphon to Greek's Gully No. 1, and there is about three-quarters of a mile of ditching constructed, on the north side of the Hokitika–Kumara Road, but it still requires about one mile of ditching to bring the water into Callaghan's, and about 25 chains of a siphon to cross the low ground at the head of the Waimea Valley. The present extension will have to be continued also for about a mile

towards Goldsborough before it can be utilised, but the most important work at the present is the deviation at the upper end of the long siphon. The estimated cost of extension towards Goldsborough is about £700, and to complete the branch to Callaghan's about £1,400. Until a survey is made of the deviation at the upper end of the long siphon no correct estimate can be formed; but, judging from the distance that the ditch will have to be taken, it will probably exceed £2,000.

There is also a portion of the race, about Greek's Gully and Fox's, where there is high fluming erected, but this is not in such a decayed state as the long flume near the head, a good deal of repairs having been done to strengthen it. When the time comes to replace the flumes in this locality it will be a question of extending the branch on the opposite side of the range, which would do away with most of the flumes on the race and several bad tunnels.

The sales of water from the Waimea Race were considerably less last year than they were for the previous one, owing to so many breakages having taken place in the high fluming on the upper portion of the race. The manager states that the repairs took about seven weeks, and cost £300. During the whole of this time no parties could be supplied with water.

The following statement will show the amount received for sales of water, the expenditure on maintenance, the number of men employed, and the approximate quantity of gold obtained by those using water from this supply :—

Month.	Sales of Water.	Cash received for Sales of Water.	Expenditure.	Outstanding Moneys at the End of each Month.	Number of Men employed.	Approximate Yield of Gold in Ounces.	Value of Gold obtained.
1893.	£ s. d.	£ s. d.	£ s. d.	£ s. d.			£ s. d.
April	62 1 8	82 15 5	64 10 11	56 15 5	64	155	604 10 0
May	88 12 8	87 14 0	70 12 4	56 15 5	68	220	858 0 0
June	95 9 4	61 13 3	75 12 11	56 15 5	67	240	936 0 0
July	72 0 10	86 15 0	67 19 10	56 15 5	65	180	702 0 0
August	77 9 4	93 18 6	75 8 2	56 15 5	65	192	748 16 0
September	73 2 11	69 18 3	70 7 4	56 15 5	67	180	702 0 0
October	76 19 2	82 17 3	63 12 2	56 15 5	74	190	741 0 0
November	89 11 10	69 6 9	72 4 10	56 15 5	74	220	858 0 0
December..	42 10 0	9 11 3	93 5 3	56 15 5	73	105	409 10 0
1894.							
January	45 4 7	65 0 6	106 19 5	56 15 5	69	112	436 16 0
February	63 12 6	79 14 6	81 3 0	56 15 5	64	158	616 4 0
March	42 0 10	37 15 0	77 13 2	57 16 11	63	100	390 0 0
Totals	828 15 8	826 19 8	919 9 4	..	67 (average)	2,052	8,002 16 0

It will be seen from the above statement that the value of the sales of water amounted to £828 15s. 8d., as against £1,015 12s. 3d. for the previous year, thus showing a decrease of £186 16s. 7d.; but this decrease is owing to the breakages before referred to. The expenditure last year was £919 9s. 4d., which leaves a deficit on the year's transactions of £90 13s. 8d. The approximate quantity of gold obtained by those using water from the water-race was 2,052oz., representing a value of £8,002 16s. Deducting the value of the sales of water, it leaves £7,174 0s. 4d. as the average earnings of sixty-seven miners, which is equal to £107 1s. 6d. a man per annum, or £2 1s. 2d. a man per week. The total cost of this work up to the present time is £130,698 16s.

Kumara Water-race.

This water-race is in very good repair, but there is no gainsaying the fact that the time is fast approaching when extensions will have to be made to command fresh ground. Four claims, which used about forty sluice-heads of water, have been worked out during the year, and, although some of the present claims will yet take many years to work out, provision will have to be made to extend the race to command fresh ground. A commencement has been made to construct a No. 4 tunnel tail-race; when this is completed it will open up a considerable area of new ground. Thirteen claims have been taken up, comprising 69 acres, between the Long Tunnel Company's workings and the main road to Hokitika, where good prospects have been obtained. The miners state that twenty-nine shafts have been sunk on this ground, and the material from such all show that it is payable ground for sluicing. The manager of the water-race had some of the material from these shafts washed, which yielded 5 grains of gold to the cubic yard. This is considered very good ground for hydraulic sluicing; before, however, it can be worked, a tunnel tail-race will have to be constructed for about 70 chains in length, which is estimated to cost about £4,500. A survey has been made of this tail-race, and an application made to the Government for some assistance towards its construction.

The estimated cost of the No. 4 tail-race which is under construction is £3,000, and a subsidy of £1,000 has been authorised towards this work. When this is completed, and the No. 5 tail-race constructed, it will give a new life to Kumara. The construction of these tail-races means an expenditure on the Kumara Race so as to be in a position to supply the claims with water. The ditch will have to be extended for about 40 chains along the side of the Kapitea Hill, and it will require a siphon about 30 chains in length to bring the water on to the ground.

The steel pipes that Pascoe and Palmer placed in the deviation of the race at Dillman's show signs of weakness. Some of them are oxidized to such an extent that there are several small holes in them. They show clearly that steel pipes are much more subject to oxidation, and also that the water has a far greater effect on them than on iron pipes. One thing can be said—that they were never well coated with tar; and this has, in a great measure, been the cause of their rapid oxidation.

The following is a statement showing the results of working the Kumara Water-race during the past year:—

Month.	Sales of Water.	Cash received for Sales of Water.	Expenditure.	Outstanding Moneys at the End of each Month.	Number of Men employed.	Approximate Quantity of Gold obtained.	Value of Gold obtained.
1893.	£ s. d.	£ s. d.	£ s. d.	£ s. d.		Oz.	£ s. d.
April	451 16 5	451 13 0	167 19 1	147 15 8	128	678	2,644 4 0
May	480 13 7	548 0 2	146 4 0	94 7 6	127	720	2,808 0 0
June	541 11 11	501 1 4	155 5 4	111 2 0	122	813	3,170 14 0
July	542 9 6	530 12 9	150 10 6	113 0 7	129	815	3,178 10 0
August	575 10 5	546 0 0	135 16 6	122 11 11	122	860	3,354 0 0
September	486 9 2	445 0 11	144 19 6	104 7 6	116	720	2,808 0 0
October	539 8 4	572 17 6	151 3 6	114 8 3	116	800	3,120 0 0
November	402 11 11	336 14 10	144 11 2	139 10 6	111	604	2,355 12 0
December	451 5 5	446 2 0	201 2 4	114 5 11	109	675	2,632 10 0
1894.							
January	303 0 10	372 0 0	187 12 1	119 18 9	104	455	1,774 10 0
February	415 5 5	268 7 0	182 16 9	160 12 3	102	620	2,418 0 0
March	392 1 8	434 16 6	149 7 8	116 9 3	105	588	2,293 4 0
Totals	5,582 4 7	5,453 6 0	1,919 8 5	..	116 (average)	8,348	32,557 4 0

It will be seen from the above statement that the value of the sales of water last year amounted to £5,582 4s. 7d., as against £5,789 0s. 9d. for the previous year, thus showing a decrease in last year's transactions of £207 16s. 2d. The expenditure on maintenance last year was £1,917 8s. 5d., as against £1,782 11s. for the previous year, thus showing an increase in the cost of maintenance last year of £134 17s. 5d. Taking the value of the sales of water and the expenditure on maintenance, it leaves a net profit on the working of £3,664 16s. 2d. In addition to the value of sales of water, the value of water supplied free of cost to those who had bad claims—or, at least, the working of which was not profitable to the owners—amounted to £1,901 10s. 3d., and water to the value of £214 10s. was given to open up new claims, and also water to the value of £89 4s. 4d. as a subsidy towards the cost of a deviation of the race. The approximate quantity of gold obtained by those who were using water from the race was 8,348oz., representing a value of £32,557 4s. Deducting the value of sales of water from this, it leaves £26,974 19s. 5d. as the earnings of 116 miners, being an average of £232 10s. a man per annum, or £4 5s. 6d. a man per week. The total cost of construction of this race up to the 31st March last was £40,984 1s. 11d., and, taking the profits on the working last year, it gave 8·9 per cent. on the capital invested.

Waimea-Kumara Water-races.

The two water-races previously referred to have to be taken in conjunction, as they practically comprise one work. They are separate water-races in one sense, but the Kumara Water-race depends on portion of its supply of water from the Waimea Water-race, which can be turned into what is known as the Kawhaka Supply-race at several points, and this keeps up the supply of water in the Kumara Reservoir, which is constructed on the south side of the Loop-line Road. Taking, therefore, this supply as one work, the following statement will show the result of the working during the last year:—

Month.	Sales of Water.	Cash received for Sales of Water.	Expenditure.	Outstanding Moneys at the End of each Month.	Number of Men employed.	Approximate Quantity of Gold obtained.	Value of Gold obtained.
1893.	£ s. d.	£ s. d.	£ s. d.	£ s. d.		Oz.	£ s. d.
April	513 18 1	534 8 5	232 10 0	204 11 1	192	833	3,248 14 0
May	569 6 3	635 14 2	216 16 4	151 2 11	195	940	3,666 0 0
June	637 1 3	562 14 7	230 18 3	167 17 5	189	1,053	4,106 14 0
July	614 10 4	617 7 9	218 10 4	169 16 0	194	995	3,880 10 0
August	652 19 9	639 18 6	211 4 8	179 7 4	187	1,052	4,102 16 0
September	559 12 1	514 19 2	215 6 10	161 2 11	183	900	3,510 0 0
October	616 7 6	655 14 9	214 15 8	170 18 10	190	990	3,861 0 0
November	492 3 9	406 1 7	216 16 0	196 5 11	185	824	3,213 12 0
December	493 15 5	455 13 3	294 7 7	171 1 4	182	780	3,042 0 0
1894.							
January	348 5 5	437 0 6	294 11 6	176 14 2	173	567	2,211 6 0
February..	478 17 11	348 1 6	263 19 9	217 7 8	166	778	3,034 4 0
March	434 2 6	472 11 6	227 0 10	174 6 2	168	688	2,683 4 0
Totals	6,411 0 3	6,280 5 8	2,836 17 9	..	183 (average)	10,400	40,560 0 0

It will be seen from the foregoing statement that the value of the sales of water last year amounted to £6,411 0s. 3d., as against £6,804 13s. for the previous year; thus showing a decrease in the sales of water last year of £393 12s. 9d. The expenditure on maintenance last year was £2,836 17s. 9d., as against £2,640 11s. 4d. for the former year; showing an increase in the cost of maintenance to the extent of £196 6s. 5d. Taking the value of the sales of water and the cost of maintenance last year, it leaves a net profit of £3,574 2s. 6d. The total cost of the work up to the present time is £171,682 17s. 11d. It has been the means of giving profitable employment to 183 miners last year, who obtained approximately 10,400oz. gold, representing a value of £40,560. Deducting the value of the sales of water from the value of the gold, it leaves £34,149 as the average earnings of the miners, which is equal to £186 12s. 2d. a man per annum, or about £3 11s. 9d. a man per week. It has to be borne in mind that a considerable discount from this amount would have to be made for the net earnings of the miners, as no allowance is made for tools and materials used.

SUMMARY showing the RESULT of WORKING the KUMARA WATER-RACE for Eleven Years, from 1st April, 1883, to 31st March, 1894.

Water supplied	Year.	Rate per Sluice-head per Week.	April.	May.	June.	July.	August.	September.	October.	November.	December.	January.	February.	March.	Total Value of Water sold.	Total Value Free for Assistance.	Total Value Free for Deviations.	Total for Construction of No. 3 Channel.	Total Value Water supplied.	Average Number of Sluice-heads supplied Daily.	Expenditure.
		£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.		£ s. d.
Water sold ..	1883–84	3 0 0	371 16 5	465 2 1	700 2 6	583 9 7	702 7 6	626 16 3	808 10 5	777 3 9	774 17 11	698 2 6	1,064 0 0	774 6 0	8,346 14 11	..	..	..	..	..	..
Free	1883–84	..	46 2 6	44 5 0	183 11 8	108 19 2	108 0 0	85 7 6	244 7 6	172 18 9	63 12 6	103 9 2	86 5 0	139 3 4	..	1,386 2 1	..	..	..	..	..
			417 18 11	509 7 1	883 14 2	692 8 9	810 7 6	712 3 9	1,052 17 11	950 2 6	838 10 5	801 11 8	1,150 5 0	913 9 4	..	..	..	..	9,732 17 0	46·35	2,153 5 5
Water sold ..	1884–85	3 0 0	580 4 4	937 19 4	667 3 11	906 16 10	882 6 10	997 1 5	919 12 3	1,126 11 10	819 17 3	289 4 2	756 9 2	821 0 10	9,704 8 2	..	..	..	..	..	..
Free	1884–85	..	92 5 0	56 19 7	78 18 9	55 13 9	149 0 10	18 11 3	145 13 4	69 3 9	39 15 0	26 12 6	45 3 9	2 16 8	..	780 14 2	..	..	..	..	..
			672 9 4	994 18 11	746 2 8	962 10 7	1,031 7 8	1,015 12 8	1,065 5 7	1,195 15 7	859 12 3	315 16 8	801 12 11	823 17 6	..	..	..	..	10,485 2 4	49·92	1,656 0 1
Water sold ..	1885–86	2 10 0	665 16 0	796 6 9	893 5 3	745 19 7	773 19 10	943 13 5	953 15 6	997 7 8	697 13 5	686 4 0	708 15 8	935 19 7	9,788 16 8	..	..	..	..	..	..
Free	1885–86	..	24 13 9	9 2 0	..	..	23 15 0	31 3 4	22 1 3	18 11 10	18 7 2	49 1 4	1 5 0	13 2 6	..	221 3 2	..	..	..	..	..
			690 9 9	805 8 9	893 5 3	745 19 7	797 14 10	974 16 9	975 16 9	1,015 19 6	716 0 7	735 5 4	710 0 8	949 2 1	..	..	..	..	10,009 19 10	57·20	1,454 19 5
Water sold ..	1886–87	2 10 0	758 0 4	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Water sold ..	1886–87	2 0 0	..	19 10 8	488 3 9	315 7 11	599 5 0	643 7 11	682 8 9	686 7 5	562 0 10	345 12 7	673 0 0	747 9 2	6,470 14 4	..	..	..	..	..	..
Free	1886–87	..	..	776 0 11	242 0 11	40 13 9	120 9 7	83 15 10	74 5 0	45 9 2	32 15 0	46 8 9	49 16 8	36 3 4	..	1,547 18 11	..	..	..	..	..
			758 0 4	795 11 7	730 4 8	356 1 8	719 14 7	727 3 9	706 13 9	731 16 7	594 15 10	392 1 4	722 16 8	783 12 6	..	..	..	..	8,018 13 3	56·19	1,398 18 10
Water sold ..	1887–88	2 0 0	535 5 10	679 7 8	167 10 10	656 4 7	684 16 1	694 5 0	591 12 1	710 0 0	535 10 10	519 15 5	670 17 6	734 4 5	7,169 10 3	..	..	..	..	..	..
Free	1887–88	..	26 11 8	40 19 2	15 13 9	23 10 0	47 7 11	4 11 8	34 16 8	42 10 0	27 10 0	28 6 8	19 11 8	15 17 3	..	347 6 5	..	..	..	..	..
			561 17 6	720 6 10	183 4 7	679 14 7	732 4 0	698 16 8	626 8 9	752 10 0	553 0 10	548 2 1	690 9 2	750 1 8	..	..	..	..	7,516 16 8	53·68	982 12 0
Water sold ..	1888–89	2 0 0	490 6 8	338 7 7	532 1 1	626 19 10	667 8 3	542 8 4	702 12 6	664 1 7	395 12 3	465 2 1	623 18 4	667 8 4	6,716 6 10	..	..	..	..	..	..
Free	1888–89	..	107 17 3	90 18 0	87 1 4	75 1 10	32 10 0	16 9 5	38 1 4	13 0 0	34 9 2	58 6 8	90 10 10	74 13 4	..	492 0 0	227 0 0	..	..	..	..
			598 3 11	429 5 7	619 2 5	702 1 8	699 18 3	558 17 9	740 13 10	667 1 7	430 1 5	523 9 7	714 9 2	742 1 8	..	..	..	..	7,435 6 10	53·10	1,024 1 9
Water sold ..	1889–90	2 0 0	401 13 4	495 16 4	256 16 8	377 16 3	353 4 2	237 7 11	318 10 10	293 8 4	159 18 9	219 15 10	248 19 7	186 16 8	3,550 4 8	..	..	..	..	..	..
Free	1889–90	..	45 15 0	55 3 4	43 0 0	92 15 0	105 15 0	93 1 8	41 10 0	103 18 4	105 13 4	48 17 6	54 8 4	71 5 0	..	396 2 6	465 0 0	..	..	..	..
Free, No. 3 Channel	1889–90	..	..	..	..	..	122 19 1	335 1 3	330 11 8	275 8 0	97 13 4	6 0 0	221 18 1	102 11 5	..	..	..	1,492 2 10	..	..	..
			447 8 4	550 19 8	299 16 8	470 11 3	581 18 3	665 10 10	690 12 6	672 14 8	363 5 5	274 13 4	525 6 0	360 13 1	..	..	..	..	5,903 10 0	42·16	1,424 13 3
Water sold ..	1890–91	2 0 0	300 12 6	355 11 11	368 3 2	423 9 0	622 17 11	666 7 1	720 16 1	701 5 10	578 1 8	546 17 11	691 17 11	689 11 8	6,665 12 8	..	..	..	..	..	..
Free	1890–91	..	113 5 0	119 14 2	70 7 11	71 17 6	82 9 7	110 16 8	93 13 9	106 0 10	57 5 5	113 6 8	133 2 6	130 5 10	..	409 5 5	793 0 5	..	..	..	..
Free, No. 3 Channel	1890–91	..	272 11 11	247 3 6	246 17 10	115 2 11	32 2 2	..	..	..	..	..	..	..	..	..	..	913 18 4	..	..	..
			686 9 5	722 9 7	685 8 11	610 9 5	737 9 8	777 3 9	814 9 10	807 6 8	635 7 1	660 4 7	825 0 5	819 17 6	..	..	..	..	8,781 16 10	62·72	1,766 4 3
Water sold ..	1891–92	2 0 0	616 5 10	655 4 11	542 9 1	179 11 11	426 16 1	769 15 5	784 13 8	642 4 2	469 10 0	291 3 9	543 7 6	724 8 8	6,645 11 0	..	..	..	..	..	..
Free	1891–92	..	143 11 5	191 16 8	44 3 6	..	82 16 11	151 14 7	118 10 1	233 1 8	213 11 3	137 0 10	64 11 8	28 9 2	..	996 4 5	413 3 4	..	..	..	..
			759 17 3	847 1 7	586 12 7	179 11 11	509 13 0	921 10 0	903 3 9	875 5 10	683 1 3	428 4 7	607 19 2	752 17 10	..	..	..	..	8,054 18 9	57·53	1,584 10 11
Water sold ..	1892–93	2 0 0	495 17 1	505 12 11	493 5 10	495 13 6	602 2 8	635 1 3	571 1 8	458 7 1	382 2 1	390 19 2	450 7 6	308 10 0	5,789 0 9	..	..	..	..	..	..
Free	1892–93	..	44 18 9	80 2 6	72 4 2	61 2 1	43 5 10	38 2 6	44 0 10	66 2 6	157 6 8	94 4 2	77 10 10	64 2 6	..	444 15 8	398 7 8	..	..	..	..
			540 15 10	585 15 5	565 10 0	556 15 7	645 8 6	673 3 9	615 2 6	524 9 7	539 8 9	485 3 4	527 18 4	372 12 6	..	..	..	..	6,632 4 1	47·35	1,782 11 0
Water sold ..	1893–94	2 0 0	451 16 5	480 13 7	541 11 11	542 9 6	575 10 5	486 9 2	539 8 4	402 11 11	451 5 5	303 0 10	415 5 5	392 1 8	5,582 4 7	..	..	..	..	..	..
Free	1893–94	..	101 5 2	119 5 7	99 4 6	110 7 1	92 9 10	147 16 2	112 11 0	164 18 5	82 0 4	112 3 10	132 15 10	70 6 10	..	1,306 0 3	39 4 4	..	6,927 9 2	49·48	1,917 8 5
			553 1 7	599 19 2	640 16 5	652 16 7	668 0 3	634 5 4	651 19 4	567 10 4	533 5 9	415 4 8	548 1 3	462 8 6	76,429 4 10	8,327 13 0	2,335 15 9	2,406 1 2	89,498 14 9	..	17,145 5 4

NOTE.—The above does not include water for flushing purposes as follows: No. 2 Channel, 10 sluice-heads; No. 3 Channel, 23 sluice-heads. The average number of sluice-heads supplied daily is calculated each year on 280 working-days per annum.

Mount Ida Water-race.

The whole of the water-race has been cleaned out and repaired. The different creek-beds through which the race crosses have all been trenched across, until a solid foundation was reached, and a strong bank of sods built up, having a heavy stone apron at the back. The thick wall of sods and stone apron comes up to within one foot of the maximum height of water in the conduit. Above this a narrow bank of sods is placed, to raise the water to the maximum height. The object of this is that, in the event of a flood taking place, the narrow bank of sods above the height of the apron will be easily carried away, and prevent the flood-water from accumulating in the ditch and breaking it away in places. The creeks are all made into bywashes. At each of the bywashes in the creeks there is a gate put in the ditch on the lower side of the bywash, so as to prevent any extra water getting down the water-race in flood time, and also to prevent the shingle from going so far down the ditch when it fills up the channel crossing the creek in heavy floods.

The cost of repairs to the water-race last year was £2,600 19s. 2d.; or, the total cost of repairs since the Government took it over from the Trust has been £2,837 6s. 3d.; and at the time the Government took the work over there were liabilities which were incurred by the Trust to the extent of £423 18s. 6d. which had to be paid. The water-race is now in very good order, with the exception of a short tunnel, which will require to have new timber placed in it next winter, during the time when the miners cannot work. The maintenance men should, for the future, be able to keep the whole of the race in good order, unless some large break takes place.

The manager has been instructed to fill up any holes burrowed out by the rabbits on the lower side of the ditch, and to have a pathway made along the bank of the race, which is being done in spare time by the maintenance men. When this pathway is completed a man can ride up alongside and examine it carefully. In the past, very little of the race was visited, unless a break actually took place. The greatest danger to the race is when the surface-sods slip into the ditch from the high side and dam up the water; and unless the maintenance men either walk or ride along the actual race-line this is not observed, and the sods are left there until the race will not carry sufficient water, or a break takes place, and then an examination has to be made.

There has been a good supply of water all the season since the race was repaired. During the month of July, and part of the month of June, the water was turned off, owing to frost; but, with this exception, the sales of water have been pretty regular. The following statement will show the results of working the water-race for the year ending the 31st March, 1894:—

Month.	Sales of Water.	Cash received for Sales of Water.	Expenditure.	Amount of Outstanding Moneys at End of each Month.	Number of Men employed.	Approximate Amount of Gold obtained.	Value of Gold obtained.
1893.	£ s. d.	£ s. d.	£ s. d.	£ s. d.		Oz.	£ s. d.
April	..	32 8 3	76 14 2	1,512 13 9	..	..	..
May	152 16 10	99 0 1	73 3 8	1,566 10 6	130	170	667 5 0
June	42 0 10	32 5 4	69 6 8	1,576 6 0	60	70	274 15 0
July	..	..	63 14 8	1,576 6 0	..	..	..
August	194 10 0	..	102 17 1	1,741 10 0	62	265	1,040 2 6
September	180 8 10	66 4 1	91 0 11	1,736 8 0	63	200	*785 0 0
October	181 15 9	223 2 9	80 7 8	1,025 3 1	68	250	981 5 0
November	177 7 6	125 2 1	76 10 8	1,034 6 5	80	250	981 5 0
December	139 10 6	280 9 4	83 19 8	1,007 11 2	74	150	588 15 0
1894.							
January	107 14 5	91 13 11	105 16 8	1,037 5 2	72	420	1,648 10 0
February	101 1 9	133 2 11	102 7 5	982 9 10	72	600	2,355 0 0
March	144 12 10	129 12 3	87 9 8	974 18 7	72	450	1,766 5 0
Totals ..	1,421 19 3	1,213 1 0	1,013 8 11	..	75 (average)	2,825	11,088 2 6

* Liabilities, £763 12s. 6d., written off.

It will be seen from the foregoing statement that, notwithstanding that no water was supplied in April, owing to the repairs being proceeded with, the sales of water for the year amounted to £1,421 19s. 3d. as against £1,396 0s. 4d. for the year previous, and the expenditure on maintenance last year was £1,013 8s. 11d. as against £1,403 for the year previous. A comparison of expenditure, however, cannot fairly be made, as the whole of the repairs last year have been charged to construction. All ordinary repairs should in future be done by the maintenance men, without entailing any extra cost. The cash received for sales of water last year was £1,213 1s., thus showing that the arrears during the year have amounted to £208 18s. 3d. The average number of men employed in the claims that have been using water from the Government race during last year has been 75, and the approximate quantity of gold obtained by them was 2,825oz., representing a value of £11,088 2s. 8d. Deducting from this amount the value of the sales of water, it leaves the average earnings of the miners to be £128 17s. 7d. for each man for eleven months' work. Since they were employed in repairing the race for the month of April, this is equal to £2 13s. 8d. per week.

Blackstone Hill Water-races.

These water-races were purchased in January, 1893, from the Official Assignee, for the sum of £1,000. They are worked in conjunction with the Mount Ida Water-race. The head of the supply-race from the branch of the Manuherikia River or Johnstone's Creek to the point where it crosses the Mount Ida Water-race has been cleaned out and widened, so that it can take a large supply of water from that creek when water is available, and when it is not all required at Blackstone Hill it can be sent down to Naseby.

An arrangement was made with Mr. Robert Johnstone last year, allowing him the use of one of the lower races, contingent on his cleaning out and keeping the others in repair. This arrangement has so far been carried out, so that no money has been expended on maintenance of these water-races for the past year.

The upper race, however, is greatly grown over, and during next spring it will have to get a thorough cleaning-out. It is possible that, by having this done, more water can be sold at Blackstone Hill, if it can be spared from the Mount Ida field. There was not water in this upper race during the months of June, July, and August, and part of May. The miners taking the water were, when idle, offered the opportunity of working at the repairs of the Mount Ida Water-race, and some of them availed themselves of the opportunity.

In order to show the result of this water-race, the sales of water have been separated from the sales of the Mount Ida Water-races, and the receipts bear out my estimate of last year. The following statement shows the results of the working of these water-races for the year ending the 31st of March last:—

Month.	Sales of Water.	Cash received.	Expenditure.	Arrears.	Number of Men employed.	Gold obtained.	Value of Gold obtained.
1893.	£ s. d.	£ s. d.		£ s. d.		Oz.	£ s. d.
April	12 16 10	12 16 10		4 3 4	9	24	94 4 0
May	2 1 8	2 1 8		4 3 4	1	5	19 12 6
June	..	..		..	..	..	..
July	..	..		..	..	..	..
August	..	..		..	..	..	..
September ..	14 2 6	10 15 10		5 8 4	9	26	102 1 0
October	13 12 6	11 5 10		7 15 0	9	25	98 2 6
November	12 19 2	11 15 10	*Nil.*	7 18 4	9	27	105 19 6
Decem er	10 12 6	8 5 10		11 4 8	9	28	109 18 0
1894.							
January	13 2 6	14 10 10		8 6 4	9	28	109 18 0
February	11 12 6	11 13 10		9 15 4	9	29	113 16 6
March	12 17 6	14 10 10		8 2 0	9	27	108 19 6
Totals ..	103 17 8	97 17 4		..	8⅓ (average)	219	862 11 6

It will be seen from the foregoing statement that the sales of water amounted to £103 17s. 8d., and the cash payments to £97 17s. 4d., while the arrangement made with Mr. Johnstone, before referred to, made the outlay for maintenance *nil*; and, as the capital invested is £1,000, the profits on the working of these water-races for the year was equal to 10⅓ per cent. per annum on the investment. The approximate quantity of gold obtained by those using water from these water-races has been about 219oz., representing a value of £862 11s. 6d. Deducting the value of the sales of water, it gives the average earnings of the miners for ten months of the year to be about £106 1s. 10d. per man, which is equal to £2 8s. 2d. per week. Some of those working with the water last year got very little gold.

Summary of Water-races.

The following statement shows the result of the working of the water-races constructed and controlled by Government, and the collateral advantages derived therefrom. It will be seen from this statement the cost of the works has been £346,714 12s. 8d., and that the actual profits derived from the sales of water, and duty on gold which was obtained by the use of water from these supplies, during the past sixteen years amount to £80,014 16s. 7d. This is a small sum for the length of time that has elapsed since these races have been completed; but they have indirectly been the means of a large population being employed, and in the localities in which these water-races were constructed the ground which they command, and which has already been worked by their aid, would have been still lying in its wild state had the races not been constructed, as the cost of bringing in the water was beyond private enterprise.

Statement showing the Profits and Losses on the Working of the Water-races for Sixteen Years.

Name of Water-race.	Value of Sale of Water, including Value of any Gold obtained in Sludge-channel.	Expenditure.	Profit or Loss on Working.	Average Number employed.	Approximate Amount of Gold.	Value of Gold obtained.	Duty received on Gold obtained.	Total Profit or Loss, with Value of Gold Duty added.	Total Cost of Construction.
Waimea-Kumara Water-race and Sludge-channel.	£ s. d.	£ s. d.	£ s. d.		Oz.	£ s. d.	£ s.	£ s. d.	£ s. d
Fifteen years ending the 31st March, 1893	126,409 5 10	77,708 11 7	48,700 14 3	360	231,256	867,262 12 3	20,728 0	69,428 14 3	..
Year ending 31st March, 1894	6,411 0 3	2,836 17 9	3,574 2 6	183	10,400	40,560 0 0	..	3,574 2 6	..
Totals	132,820 6 1	80,545 9 4	52,274 16 9	349	241,656	907,822 12 3	20,728 0	73,002 16 9	171,682 17 11
Nelson Creek.									
Thirteen years four months ending the 31st July, 1892..	17,577 0 7	15,415 7 1	2,162 13 6	52	32,943	126,049 17 0	3,269 16	5,431 9 6	90,722 10 8
Argyle.									
Thirteen years ending the 31st March, 1891	5,530 16 10	5,455 7 7	75 9 3	17	8,040	30,738 12 0	804 0	933 3 11	14,701 15 3
Mount Ida.									
Fifteen years ending the 31st March, 1893	20,182 1 9	23,776 14 4	3,612 12 0	108	38,461	145,975 10 0	3,176 2	238 16 1	..
Year ending 31st March, 1894	1,421 19 3	1,013 8 11	408 10 4	75	2,825	11,088 2 6	..	408 10 4	..
Totals	21,604 1 0	24,790 3 8	4,021 2 4	106	41,286	157,063 12 0	3,176 2	647 6 5	69,607 8 9
Grand totals ..	177,532 4 6	126,206 7 8	58,534 1 10	524	323,925	1,221,674 13 9	27,977 18	80,014 16 7	346,714 12 8

ERRATA IN SUMMARY OF WATER-RACES, PAGE 28.

WAIMEA-KUMARA WATER-RACE AND SLUDGE-CHANNEL.

THE total cost of construction for the Waimea-Kumara Water-race and Sludge-channel for the sixteen years should be £171,655 2s. 1d., instead of £171,682 17s. 11d.; and the grand total of same column should be £346,686 16s. 9d., instead of £346,714 12s. 8d.

MOUNT IDA WATER-RACE.

IN column for "Profit or Loss on Working," the figures for fifteen years ending 31st March, 1893, should be £3,594 13s. 0d., instead of £3,612 12s. 0d.; and the total for the sixteen years ending 31st March, 1894, should show a loss on working of £3,186 2s. 8d.; the grand total of the column being thus £51,326 16s. 10d., instead of £58,534 1s. 10d. Also, in column "Total Profit or Loss with Value of Gold Duty added," the figures for the fifteen years ending 31st March, 1893, should be £418 11s. 0d., instead of £238 16s. 1d.; and the total for the sixteen years ending 31st March, 1894, should be a loss of £10 0s. 8d.; the grand total of the columns being thus £79,357 9s. 6d., instead of £80,014 16s. 9d.

GOLD- AND SILVER-MINING.

The result of gold-mining operations last year has, on the whole, been satisfactory, notwithstanding the fact that the days have gone past for rich patches of auriferous gravels and quartz being easily got. The quantity of gold produced last year was 12,043oz. more than for the previous year, and there has been a decrease in the actual number of miners employed to the extent of 644. This shows that by improved methods of working the ground, and better appliances and mode of recovering and saving the precious metal from ores and alluvial drifts, more gold can be obtained with less labour than in former years. The following statement will show a comparison with the yield of the previous year:—

Name of District.	Year ended 31st March, 1894.		Year ended 31st March, 1893.		Increase for 1894.	Decrease for 1894.
	Oz.	£	Oz.	£	Oz.	Oz.
Auckland	52,426	215,012	41,052	165,849	11,374	..
Marlborough	2,262	9,037	3,055	12,083	..	793
Nelson	2,179	8,141	2,792	10,609	..	613
West Coast	98,930	395,738	101,636	406,523	..	2,706
Otago	84,905	342,302	80,124	322,403	4,781	..
Totals	240,702	970,220	228,659	917,467	12,043	..

The above statement shows an increase in the Auckland District of 11,374oz. Of this amount there has been an increase in the Ohinemuri County of 10,933oz.; Thames Borough, 960oz.; and Thames, 108oz.: a decrease of 598oz. in Coromandel County, and 29oz. in Piako County and Whangarei. In Marlborough there was a decrease in the yield of gold last year to the extent of 793oz.; in Nelson, 613oz.; and in the West Coast districts to the extent of 2,706oz. In some portions of the district—namely, in Inangahua County—there has been an increased yield to the extent of 3,353oz., and in the Ross Borough 127oz.; but there has been a decrease in the yield in the Buller County to the extent of 190oz., Grey County 2,882oz., Westland County 2,253oz., Borough of Kumara 363oz., and in the Borough of Hokitika 498oz. In Otago the increased yield of gold last year was 4,781oz. This increase was, in Tuapeka County, 4,389oz.; Vincent County, 2,173oz.; Waitaki County, 601oz.; Bruce County, 131oz.; Lake County, 198oz.; Stewart Island, 70oz.; and Bruce County, 8oz.: while there has been a decrease in the yield—in the Taieri County of 265oz., in Maniototo County 123oz., in Waihemo County 829oz., in Waikouaiti County 169oz., in Wallace County 756oz., in Fiord County 292oz., and in Southland County, &c., 355oz.

The large increase in the yield of gold last year in the Ohinemuri County is due to the more extensive workings of the Waihi Gold- and Silver-mining Company, also the produce from the Crown Company's mine at Karangahake, and Mr. Russell's mine at Waitekauri.

Although there is a considerable percentage of silver in the bullion from the mines in the North Island goldfields, there is no one working silver-ore by itself. The silver is extracted from the bullion by the banks, and it is only from this source that silver has been obtained. At Karangahake, Waihi, Waitekauri, and Waiorongomai there is a larger percentage of silver in the ore than that found at the Thames and Coromandel; but even at the last-mentioned places the gold obtained is alloyed with silver, which reduces the price of the gold considerably below what is obtained in the Middle Island. Some of the gold obtained at Coromandel is worth about £3 per ounce, and this is considered a high price, whereas at the Thames the average value of the gold does not exceed £2 14s. per ounce. During last year 63,076oz. of silver was extracted, representing a value of £9,743, as against 22,053oz., valued at £3,996, for the previous year, which shows an increase in the quantity exported last year of 41,023oz., representing £5,747.

QUARTZ WORKINGS.

NORTH ISLAND.

AUCKLAND DISTRICT.

Puhipuhi.

So far, the gold- and silver-lodes in the Puhipuhi district have not proved remunerative for working, but, with the exception of the Prospectors' Claim, there has been very little work done to prove whether the lodes contain sufficient gold and silver for working. In regard to the Prospectors' Claim, the richest ore was found near the surface; yet none of this could be worked at a profit. This, however, is due to a great extent to the crude machinery and appliances used by the Prospectors' Company. Very few of the shareholders, if any, know anything about mining, and more especially in regard to the extraction of silver from its ores. Some of them, it is said, knew a little about assaying, and this little knowledge, no doubt, led them to suppose that they knew more about the metallurgy of silver than they did; but the mere knowledge acquired from reading books on the subject, without having a practical experience, contributed to a great extent to the various failures made in dealing with the ore. The field is one which is well worthy of prospecting, as silver is known to exist in the lodes. At the same time, there is nothing to warrant the formation of any large company at the present time to erect expensive machinery and appliances to work any of the lodes, as far as they have been prospected. Before erection of machinery, any company or private party would probably require to spend several thousand pounds to prospect the different lodes to see whether there is sufficient ore of a payable character for working to justify further expense.

The Puhipuhi field is not a place for poor men to come to with the object of taking up ground to earn a livelihood. It will require a considerable amount of capital to prospect and develop it, and, even if a large body of payable ore were found, capital would be required to erect a plant to

treat the ore successfully. Rich assays have been from time to time made of ore from this field. Some samples sent to the Colonial Laboratory showed it to contain at the rate of over 1,000oz. silver to the ton, but samples forwarded for assay are in general misleading, as it is almost impossible for those interested in a mine to pick out an average sample of the ore in a lode. Pieces of stone are sent away which has the appearance of carrying mineral, and if it had not that appearance it would be thrown on one side. On my visit to this field, when prospecting was being carried on, there appeared to be a fair percentage of the ore in the lode carrying silver, but on getting down the percentage seemed to get gradually less. In all lodes the metal or mineral they contain never continues uniform for a long distance along their line, but occurs more generally in shoots and ledges—that is, the lode might be almost barren in places, and in other places contain rich ore. Some of the lodes on the field are well defined, while others are more of a broken rubbly character, with the ore merging into the walls of the country rock.

When such rich specimens have been found, one would naturally suppose that rich ore will yet be obtained on this field, but it must not be supposed that this assumption will be borne out. No one can be certain of the value of ores buried in the bowels of the earth. The character of the lodes leads one to form conclusions as to the possibility of metals or minerals being found in them. All that can be said of the lodes at Puhipuhi, there is a fair possibility of payable ore being found; but the prospector, or those carrying on prospecting operations, will have to bear with many disappointments; but my impression is that it will yet be a field which will support a fair mining population. At the present time there is no mining being carried on. The ardour of those who embarked their capital is completely damped by the unfortunate results met with by the prospectors, and it can be truly said that the obsolete machinery and crude appliances used by the Prospectors' Company has done a great deal of harm to the field, and given it a bad name, which will take years to efface before people will again be induced to carry on prospecting operations energetically.

Whangarei.

In December last considerable excitement was caused by a reported find of a large auriferous and argentiferous deposit at Parihaki, about three-quarters of a mile across the river from the township. The deposit consists of decomposed rhyolite, some of which is very compact, at the same time absorbent. It runs along the face of the hill for a considerable distance, and, if proved to contain precious metals, would have been very valuable property. A number of samples were taken to Mr. G. Clark Walker for assay, and one of these is said to have given, on analysis, at the rate of 59oz. of silver to the ton. The samples came from Mr. D. Horn's property. The adjoining property where this deposit passes through belongs to Mr. R. Reyburn, who had his ground prospected, and samples were sent by Mr. W. A. Carruth to Mr. Rodes, of the Bank of New Zealand, at Paeroa, who got gold at the rate of from £2 to £6 2s. per ton. Mr. Neil McLean, about the same time, is said to have sent samples to the Thames School of Mines, which gave similar results. Mr. Carruth sent away further samples, and again got results which showed the assay-value of the samples to be as high as £7 per ton; and in the meantime Mr. Clark Walker was assaying the ore and getting gold.

An association was formed consisting of fifteen members, and Messrs. Carruth, Cooke, and Alderton were appointed a committee of management; and arrangements were made with Mr. Reyburn to work this deposit. Such was the position in January last, when the Hon. the Minister of Mines requested me to visit and examine the material. Several samples were taken by me from this deposit from the same place, Mr. Reyburn informed me, that the other samples came from, and these were sent to Mr. Park at the Thames School of Mines to carefully analyse; and the result of his analysis was that he could not get a trace of gold in any one of the samples forwarded. Although the material formed a very compact mass, if dried, the stone would absorb a considerable quantity of moisture, and, if it had then been steeped in a solution of chloride of gold or cyanide of gold, it would give high results on analysis.

Cinnabar.

A syndicate of gentlemen from Auckland has taken up a claim on Puhipuhi, with the purpose of prospecting for cinnabar on the slopes from the tableland forming the watershed of the Wairiki Stream. The prospecting operations, so far, have been confined to an area of about 50 acres. Cinnabar is found amongst the drift-wash in the beds of the streams, and also amongst the surface material within that area. A considerable amount of work has been done by the syndicate in sinking holes and trenching on the surface, and cinnabar has been found in small quantities. It is more readily found in the beds of streams where considerable stripping has been done; and the prospectors have got somewhere about 100lb. of the ore, which was all greatly rounded, the grains being from fine particles up to about the size of a walnut.

It is expected to find a lode of the ore in the solid rock, but, as there is a heavy surface-deposit, it makes it difficult to trace the source from which the ore has come. Three drives have been put in to the solid country, and it is intended to put in cross-drives from these with the view of cutting a lode, but, so far, they have not been successful in finding one. Some of the samples of the ore sent to the Colonial Laboratory, which were analysed, gave 84·21 per cent. of mercury. This part of the Puhipuhi field was examined by Mr. A. McKay, the Mining Geologist, in 1892, and, from his observations made at that time, he found one sample with cherty quartz adhering to it, indicating that it is likely to be found in formation where quartz is got, and not in the volcanic rock which overlies a great portion of the tableland.

COROMANDEL.

This is the district where gold was first obtained in the colony. As early as 1852 Mr. C. King found gold in a small creek, and numerous auriferous quartz specimens were found in the bed of this creek before any of the reefs were discovered. Since then very rich auriferous lodes have been found, and for a large number of years a large mining population found profitable employment in working the lodes, leaders, and string-like veins of auriferous quartz on the Tokatea Range, and up to the present time rich finds are occasionally met with. During last year about 37¾ tons of quartz

were crushed, which yielded 557oz. gold, which is equal to about 14¾oz. gold to the ton. This, at first sight, appears to be a large yield, but when it is taken into consideration that twenty-six men were employed during the year to obtain this quantity of gold, it only amounts to 21oz. 8dwt. per man, representing a value of about £64. There is a very large lode running through this hill known to be gold-bearing, but, so far, where it has been tested the quartz is of too low grade to pay for working with the appliances on the field; but, no doubt, the time will come when a company with sufficient capital will take up this ground and erect a large plant to work the lodes traversing this range on a large scale.

Heretofore it has been a capital field for the individual miner; the upper portion of the range is tunnelled and worked in all directions, not on any large lode, but following the string-like veins of quartz which run in all directions through the country rock, the latter being a tufaceous sandstone. Wherever a vertical stringer of quartz cuts a flat one, generally rich patches of auriferous quartz are obtained. During last year nine men were working for themselves on ground of this character, and from 25½ tons of stone they obtained 181oz. 17dwt. of gold; and in the claims known as the Tokatea, Royal Oak, Bismarck, and Great Tokatea, seventeen tributers were employed, who obtained 12 tons of stone, which produced 375oz. 3dwt. gold.

Kapanga and Coromandel Companies.—Both these are under one management, and they are carried on with English capital. In the Kapanga Mine there are two parallel lodes—the Kapanga and Scotty's—which have an underlie to the south-south-west. The foot-wall of Scotty's lode and the hanging-wall of the Kapanga are both of hard compact rock, but the hanging-wall of Scotty's and foot wall of the Kapanga is of a soft, kindly rock, and similar in character, indicating that both these lodes form one in other portions of the ground, and that where they have been worked in the Kapanga Mine there is what may be termed a huge horse of mullock in between them. The Kapanga lode has not so much underlie as Scotty's, and, in all probability, they will be found to join at a greater depth. Scotty's lode is peculiarly formed; the lode-fissure is full of a soft, black, puggy material, with detached quartz through it; and when this puggy material is puddled up and washed the quantity of fine gold there is in it is astonishing. The appearance of the lode would lead one to suppose that the lode and country rock has been greatly crushed up by some violent disturbance, or great displacement, although no great displacement of the country rock can be observed; and the character of the rock is such that it is difficult to trace any displacement in the underground workings.

The Kapanga lode is generally small, hard, and compact, and highly mineralised. Some very rich stone was got from this lode on the upper levels, but where it was cut at the 400ft. level it contained little or no gold; but on sinking down to the 600ft. level a little gold was found in the stone. At the time of my visit the shaft was sunk to a depth of 620ft. Since then an additional 100ft. has been sunk, and, from the appearance of the country, there is a great probability of a good shot of gold-bearing stone being found at lower levels. A drive was put in at the 600ft. level, and Scotty's lode cut, which showed a little gold in the bottom of the level in one place. The dip of the lode varied considerably; still, the underlie was greater than the Kapanga lode, and there is a fair chance of these lodes meeting at a moderate depth. If a junction be effected as indicated, there is a good prospect of getting a good block of highly-auriferous stone. No one can see what is in the bowels of the earth, but the indications of success in this mine are such that fully warrant the manager going to the expense of sinking, to test the lodes at a lower level.

The Coromandel Mine was practically closed at the time of my visit, there being only a few tributers working on the upper levels, and they were at that time getting poorly paid for their labours; but recently they got some very rich stone, and at present there are between thirty and forty men at work. The place known as the John Bull Gully, which is a portion of the Coromandel Special Claim, is the principal centre of operations. In the *Coromandel News* of the 15th May last it states that the first to discover gold in this locality was Edmonds and party, who have had several nice crushings. During the past three days they have been getting rich golden stone, some of it carrying from 2oz. to 3oz. of gold to the pound. Colthurst and Ross next got gold, and they were so well satisfied with the results obtained while sinking that they started to drive a level of about 450ft. in length through Messrs. Legge's section, to enable them to get under the rich area. They have driven the tunnel about 280ft., and when in 270ft. they cut a new reef in Messrs. Legge's tribute section. This lode is a body of solid stone, about 2ft. in width, its course being north-west by south-east, with a considerable underlie to the north. The ore broken out in the width of the drive amounted to a ton and a half, and a few pounds of the stone showed rich gold; and on the whole of the stone being crushed at the Kapanga battery 22oz. of retorted gold was obtained.

Messrs. Warner and Son are likely to get a good portion of the new reef, and Messrs. Ryan and Norris, who are working the section higher up than Edmonds and Legge and party, are getting a little gold. Mr. Ryan had a parcel of 1 ton crushed, which yielded 4½oz. of retorted gold. Several other parties are prospecting in the ground adjoining the Coromandel Special Claim. Messrs. O'Sullivan and McDonald have driven an adit for a distance of 160ft., and it is considered probable that they will cut this new reef further ahead, as it is near the place where Messrs. Legge are working. This party have had a good return from a lode near the mouth of their adit-level. The discovery has caused quite a stir in the Coromandel district, and may have the effect of prospecting being more vigorously carried on, and other reefs discovered. This portion of the Coromandel is merely scratched on the surface, and not even much prospected at shallow depths.

The Kapanga and Coromandel Companies have expended a large sum of money without yet getting any adequate return. At the end of the previous year they had a direct loss on the money expended in the colony, exclusive of the purchase of machinery in England, and expenses of the London office, of £38,254, and, as the work of sinking the Kapanga shaft has been going on during the past year, a considerable sum must now be added to this loss. During the past year there have been thirty men employed on wages, and fourteen men working on tribute. The quantity of stone raised by wages-men was 288 tons and 180lb. of specimens, which yielded 512oz. 12dwt. gold; and 31½ tons of quartz was got by the tributers, which produced 348oz. gold.

Kauri Block.—This block includes the Coromandel Special Claim, which has been previously referred to; but there are two other claims—namely, the Iona and Premier, in which two men have been employed during the past year. They obtained 20½ tons of stone, which yielded 50oz. 4dwt. gold.

Waikoromiko.—Some very rich patches of auriferous stone have been got in this locality in former years, and during the past year two men in Power's claim obtained 1 ton of stone, which yielded 138oz. of gold. This was the best return last year in this portion of the district. There were four claims being worked during last year, in which six men were employed. They obtained about 8 tons of quartz, which yielded 255oz. 6dwt. gold.

Opitonui.

There are three claims in this portion of the field, in which four men are employed, who obtained during the last year 67½ tons of quartz, which yielded 99oz. 8dwt. gold. There was also 128 tons of tailings treated, which produced 16oz. 19dwt. gold.

Matarangi.

Great hopes are entertained about this field; several parcels of stone were shipped to the crushing batteries at the Thames, and gave fair returns. A syndicate has purchased the property, and have erected a crushing battery of fifteen heads of stamps, two Watson-Denny pans, and two berdans which will be driven by steam-power; but the water for the battery has not yet been brought in, so that no crushing has yet taken place at their own plant. During the last year 120 tons of quartz was crushed, which yielded 92oz. 15dwt. gold, and eight men were employed.

KUAOTUNU.

This is a field where considerable mining operations have been carried on during the past year. Ninety-seven wages-men and ten tributers have been employed. The wages-men obtained 9,332 tons of quartz, which yielded 4,143oz. 15dwt. gold; and 328 tons were raised by tributers, which produced 488oz. 15dwt. gold. In addition to this, 2,189 tons of tailings have been treated by the cyanide process, with the result that 3,420oz. 4dwt. of gold was obtained; and 51 tons of tailings treated by amalgamation yielded 21oz. 7dwt. gold. The result of last year's operations has given 4,602oz. 10dwt. gold from 9,660 tons of stone; and 3,441oz. 17dwt. gold was recovered from 2,240 tons of tailings: making the total yield from the field last year 8,043oz. gold, and 107 men were employed. During the previous year the total yield of gold from the field amounted to 9,506oz. 17dwt. gold, and 142 men were employed. Although the yield of gold is less for the past year, the average yield per man employed is 75oz. 3dwt., whereas for the previous year it amounted to an average of 64oz. 13dwt. per man. The gold on this field is extremely fine, and specially suited for treatment by the cyanide process, and the yield last year is greatly due to the adoption of this process of treatment. There are only two Cassel plants yet on the field—namely, one erected at the Try Fluke Company crushing-battery, and the other at the Great Mercury Company's battery. Before these plants were erected a large percentage of the gold was carried down the creek with the muddy water from the tables. The three principal mines being worked last year were the Try Fluke, Red Mercury, and Great Mercury.

Try Fluke Mine.—This mine was worked entirely by wages-men, who obtained 6,304 tons of quartz, which yielded 2,059oz. 10dwt. gold; and 1,204 tons of tailings were treated by the Cassel process, which gave 3,074oz. 6dwt. gold. It almost seems incredible that this quantity of gold was left in the tailings, being at the rate of 2oz. 11dwt. gold to the ton. Nevertheless, this is the return furnished by the company, as required by the Mining Act. When it is taken into consideration the stone, from the time the company began to crush at their own battery to the 31st March, 1891, did not average more than 1oz. 15dwt. gold per ton, and this was the richest portion of the lode crushed at the company's battery, and since then the stone has not averaged 1oz. to the ton, this would show that the loss of gold was appalling, irrespective of the loss by the muddy water before referred to. It is taken on the basis that the ore in the first instance, by the ordinary battery process, yielded 1oz. 15dwt. gold, and from these tailings 2oz. 11dwt. gold was obtained. It shows that only about 41 per cent. of the gold was got in the first instance, and that 59 per cent. was got out of the tailings; but, as there was a considerable loss irrespective of this, it is questionable if more than 33 per cent. of the assay-value of the ore was obtained in the first instance. This proves conclusively that different methods of treatment will have to be adopted other than the ordinary battery process; and, on fields where the gold is fairly disseminated through the stone, the Cassel process is the best that has yet been introduced.

Red Mercury Mine.—The returns from this mine show a considerable falling-off from that of the previous year. During last year 743 tons were crushed, which yielded 703oz. 12dwt. gold, and for the previous year 2,291 tons of stone were crushed, which produced 2,307oz. 2dwt. gold. This shows a large falling-off in the quantity of quartz crushed and the yield of gold. A new level was driven to cut the lode at a lower level, but it was found that the stone was not of a payable character for working. A good deal of prospecting operations and dead work has been carried on during the past year. The manager is under the impression that he will yet strike another block of auriferous stone further to the southward than where he has yet driven.

Great Mercury Mine.—The yield from this mine last year has not come up to expectations. A great deal of dead work had to be done during the year, which has increased the expenditure without receiving adequate remuneration. During the past year 1,894 tons of quartz were crushed, which yielded 1,084oz. 14dwt. gold, and 985 tons of tailings were treated by the cyanide process, which yielded 345oz. 18dwt. gold. Thirty men were employed in the mine and about the works.

There are twelve other claims being worked—namely, the Just in Time, Irene, Otama, Black Jack, and Waitaia—which are all worked on tribute, in which fourteen men were employed. There were 328 tons of stone crushed in aggregate from these claims, which yielded 458oz. 15dwt. gold. The claims known as the Lucky Hit, Aoieri, Kapai and Vermont, Loyalty, Invicta, Perseverance, and Victoria were either worked by the owners or wages-men, and from these claims 234 tons of quartz were crushed, which yielded 222oz. 9dwt. gold, and thirteen men were employed.

The Kuaotunu field is one from which a good deal of gold will be obtained, but, take it on the whole, the auriferous lodes will not be found to contain high-grade ore. There are numerous reefs containing a little gold, but a cheaper and more effective method will have to be adopted in working them and treating the ore before many of them can be made remunerative for working. The workings so far show that the lodes get poorer as they go down; but this only applies to those which are found outcropping on the surface. There is no reason why other lodes which never reach the surface will not be cut at deeper levels. The whole of the gold on this field is of an extremely fine character, being distributed in the quartz in the finest atoms of dust. To recover gold of this description requires not only very fine crushing but also very careful treatment, to be able to extract a fair proportion of the gold the ore contains.

Locality and Name of Mine or Company.	Area of Land held.	Average No. of Men Employed.		For Owners.		For Tributers.		Tailings.		
		Wages-men or Owners.	Tributers.	Quartz crushed.	Gold obtained by Amalgamation.	Quartz crushed.	Gold obtained by Amalgamation.	Quantity treated.	Gold obtained. By Amalgamation.	Gold obtained. By Cyanide
	A. R. P.			Tons cwt. lb.	Oz. dwt. gr.	Tons cwt. lb.	Oz. dwt.	Tons.	Oz. dwt.	Oz. dwt.
Coromandel County.										
Tokatea—										
Tokatea	14 2 0	..	8	..	..	5 0 0	101 11	..	..	..
Royal Oak	10 2 27	..	5	..	..	5 10 0	194 15	..	..	..
Bismarck	11 1 38	..	3	..	..	1 0 0	69 17	..	..	..
Harbour View	5 0 0	2	..	2 0 20	31 4 0	..	..	..	..	..
Try Again	5 3 30	3	..	0 8 14	45 2 9	..	..	..	..	..
Queen of North	4 0 0	2	..	1 8 0	5 3 0	..	..	..	..	..
Great Tokatea	14 2 0	..	1	..	..	0 13 41	9 0	..	..	..
Sundries	..	2	..	21 15 40	100 8 0	..	..	..	..	..
	66 0 15	9	17	25 11 74	181 17 9	12 3 41	375 3	..	..	..
Kapanga—										
Kapanga and Coromandel..	108 0 3	30	14	288 1 68	512 12 3	32 10 72	348 0	..	..	..
Scotty's..	20 0 0	..	1	..	..	7 11 0	15 12	..	..	..
	128 0 3	30	15	288 1 68	512 12 3	40 1 72	363 12	..	..	..
Kauri Block—										
Iona	2 0 0	1	..	4 0 4	11 10 0	..	..	20	15 18	..
Premier	5 0 0	1	..	16 9 0	38 14 0	..	..	..	..	..
	7 0 0	2	..	20 9 4	50 4 0	..	..	20	15 18	..
Tiki—Emily	..	1	..	..	5 0 0	..	..	..	..	..
Waikoromiko—										
Power's	10 0 0	2	..	0 19 0	138 0 0	..	..	..	..	..
Neil's	2 0 0	1	..	1 0 0	15 7 0	..	..	..	..	..
Lillis's	10 0 0	2	..	3 10 8	63 19 0	..	..	..	..	..
Kennedy's	2 0 0	1	..	2 10 0	38 0 0	..	..	..	..	..
	24 0 0	6	..	7 19 8	255 6 0	..	..	..	..	..
Opitonui—										
Little's	10 0 0	4	..	67 0 0	63 3 0	..	..	128	16 19	..
Murphy's	10 0 0	..	..	0 0 79	24 5 0	..	..	..	..	..
Sundries	5 0 0	..	..	0 7 2	12 0 0	..	..	..	..	..
	25 0 0	4	..	67 7 81	99 8 0	..	..	128	16 19	..
Mahakirau—Bryce's ..	12 0 0	4	..	0 0 18	6 10 0	..	..	..	..	..
Matarangi—										
Ocean View Extended ..	29 1 35	6	..	38 0 0	31 15 0	..	..	..	..	..
Welcome	10 0 0	2	..	82 0 0	61 0 0	..	..	..	..	..
	39 1 35	8	..	120 0 0	92 15 0	..	..	..	..	..
Kuaotunu—										
Try Fluke	24 0 7	34	..	6,304 0 0	2,059 10 0	..	..	1,204	..	3,074 6
Kuaotunu	15 0 0	2	..	157 0 0	73 10 0	..	..	..	..	..
Red Mercury	19 0 28	14	..	743 0 0	703 12 0	..	..	..	..	..
Great Mercury	28 0 12	30	..	1,894 0 0	1,084 14 0	..	..	985	..	345 18
Just-in-Time	8 2 24	..	3	..	..	147 0 0	107 19	..	..	..
Irene	7 2 0	2	..	..	..	14 0 0	19 4	51	21 7	..
Otama	29 1 20	..	3	..	..	2 0 40	52 15	..	..	..
Black Jack	10 1 3	2	..	..	..	102 0 0	97 15	..	..	..
Waitaia..	30 0 0	..	4	..	..	63 0 0	181 2	..	..	..
Lucky Hit	11 0 18	1	..	21 0 0	15 10 0	..	..	..	..	..
Aoieri	10 0 0	2	..	113 0 0	96 15 0	..	..	..	..	..
Kapai and Vermont ..	22 0 0	2	..	3 0 0	17 0 0	..	..	..	..	..
Loyalty..	5 0 0	1	..	7 0 0	8 5 0	..	..	..	..	..
Invicta	6 0 0	1	..	19 0 0	22 11 0	..	..	..	..	..
Perseverance	3 0 0	2	..	31 0 0	41 11 0	..	..	..	..	..
Victoria	4 0 0	1	..	30 0 0	8 0 0	..	..	..	..	..
Sundries	..	3	..	10 0 0	12 17 0	..	..	..	..	..
	233 0 32	97	10	9,332 0 0	4,143 15 0	328 0 40	458 15	2,240	21 7	3,420 4
Totals	534 3 5	161	42	9,861 10 29	5,734 7 12	380 5 41	1,197 10	2,388	54 4	3,420 4

NOTE.—The areas shown do not include the whole of the land occupied, but only that from which the returns are derived.

THAMES.

As year by year passes by, the workings in the mines are getting deeper, and consequently more expensive to work. The heavy charges for drainage, with the yields from the mines falling off, is becoming a drag on the shareholders, and it appears to any one visiting the field that the day is not far distant when several of the companies will have to suspend operations. The great cry in the district is, "Test the deep levels"; but to do this requires more capital than the present companies can find; and, in addition to this, there has not yet been any feasible scheme put forward to give sufficient encouragement to capitalists to invest money to prospect the deep levels. The ground on this field was extremely rich in some portions of the lodes, especially near the outcrops at the northern end of the field. At the Kuranui Hill the most of the gold was got close to the surface, and it appears to trend in a southerly direction from where it was found on the Shotover Claim, in a belt of ground having several lines of reef or lodes traversing through it at almost right-angles to the direction of the auriferous band of country.

The belt of country where the greater portion of the gold has been obtained is between the Shotover and Queen of Beauty Claims. At the former claim the gold was got at and near the surface, while at the Moanataiari Claim the best of the gold was some distance below the surface; and the richest portion of this band or belt of country seems to have gradually got deeper as it went southerly, as has been proved in the old Caledonian, Waiotahi, Cambria, Deep Level, Cross, Prince Imperial, Saxon, and Queen of Beauty Mines. The Prince Imperial Company did not get on to this band until it was down nearly 300ft. below the level of the surface on the flat. Comparing the level of the place where the rich patch of gold was found in the Shotover Claim, and the depth at which it was found in the Prince Imperial Claim, there is a difference of about 462ft. The distance from the Shotover to the Prince Imperial shaft is something like 2,442ft., and the depth being 462ft., it shows the highly auriferous portion of the band or belt of country referred to is dipping in a southerly direction of 1 in 5·3, or at an angle of nearly 11 degrees. Coming southward from the Prince Imperial, the depth in the Saxon and Queen of Beauty Mines corresponds with this dip, and the inference to be deduced from this is, that there is a high probability of rich auriferous stone being found to the southward of the Queen of Beauty shaft—and very little work has been done in this direction.

The most recent workings at deep levels to the south end of the field were in the Saxon Mine, the deepest level being 475ft. below the surface. The stone underfoot in this level showed that it was equally as good as that worked above it; and in the adjoining mine—the Queen of Beauty—payable stone was cut at about 740ft. deep in No. 11 level. Mr. Thomas Radford, who was manager of the Queen of Beauty Company when the pumping machinery broke down and operations in the mine were suspended, states that from the No. 11 level a cross-cut was driven for a distance of 48ft., when No. 1 reef was cut and was driven on for a distance of about 113ft.—namely, 30ft. to the south of the cross-cut and 83ft. to the north. As far as was driven, the reef was well defined and heavily impregnated with mineral. No stone was crushed from this reef, but Mr. Radford has no doubt as to its payable nature. A cross-cut was driven for a distance of 86ft. from the shaft, where a leader was cut which showed gold. About 40ft. was driven on this leader, and favourable indications of gold were got up to the last day of working. In carrying on the cross-cut for 24ft. beyond the point where the leader was cut, a lode was struck giving off a large quantity of strata on several occasions. Mr. Radford stated he saw gold, and forwarded samples of the stone to the directors. A specimen of the stone was shown me which came from this level, and showed gold very freely.

On making inquiries of the mine-managers on the field as to the different runs or auriferous bands of country, they all agree that these dip in a southward direction. Mr. Radford, in a report to the Queen of Beauty Extended Company, states that from the surface down to 350ft. the whole length of the lodes were payable for working, enabling good dividends to be paid; but for 150ft. below this level the lodes were not nearly so good. At the No. 8 level—537ft. below the surface—the lodes were found as good, if not better, than ever they had been before. This run of gold continued down to a depth of 677ft., when the stone became of a lower grade; but on sinking the shaft the country rock improved in character, and Mr. Radford is highly impressed that a good shot of gold-bearing stone will be got at deeper levels. This mine was abandoned owing to the company having insufficient funds to erect a new pumping plant. The plant they had consisted of two columns of pumps 12in. in diameter. Before the machinery broke down these pumps, which had a 6ft. stroke, were driven at the rate of twelve and thirteen strokes per minute, and even at this speed the pumps were not able to contend with the water. So that it was not a question of repairing the breakage which took place, but one of entailing a large outlay in entirely new machinery and pumps.

The question of further prospecting the Thames Goldfield at deep levels certainly points to the country south of the Queen of Beauty shaft, as this is a portion of the field where very little work has been done, and necessarily so, because the gold-bearing ledge or band of country is apparently at a considerable depth, and could not have been prospected without powerful drainage machinery. It must not, however, be lost sight of that this portion of the field has slipped away from the back range, causing a vertical dislocation of from 500ft. to 700ft. The amount of dislocation cannot be accurately determined; but by taking the horizontal distance—from where the Moanataiari adit-level cut the slide, at 30ft. above the sea-level, to where it was cut by a level put in from the bottom of the Big Pump shaft, about 620ft. below sea-level—as about 8½ chains or 561ft., the vertical distance being about 650ft., and if the inclination of the face of the slide be taken at from 45 degrees, then the vertical displacement would be about 561ft.; but it would be more if the angle of inclination was steeper; therefore the vertical dislocation may be fairly set down within the limits stated.

On the geological map prepared by Mr. Park, it is indicated that the Queen of Beauty shaft is in a syncline basin, and that the strata rises both north and south from near this point on the field. On the north side, the Tararu breccias can clearly be seen dipping towards this basin—if it can be so termed ; but the indications of the breccias rising again as they pass to the southward are not so well defined.

The present companies are not in a position to find the necessary capital, neither is there any tangible scheme brought forward to induce capitalists to come to their assistance. The ground is at present held by several companies—the Moanataiari, Hazelbank, Waiotahi, Cambria, Victoria, Prince Imperial, May Queen, and Queen of Beauty Extended; and each company places so considerable a value on their ground that at the present time it would be a difficult matter to bring about any scheme which would be likely to give interest on the outlay required.

As far as the deep levels at Grahamstown are concerned, the ground below the 500ft. level would require to be given up by the several companies, and the whole of the ground on the flat below that depth formed into one claim. The present pumping appliance is not sufficient to pump the water from a much greater depth, and the cost of working it is very heavy. New pumping appliances would have to be erected, and the cost of sinking a shaft to the depth mentioned by the people at the Thames—1500ft.—with levels and opening out the ground, would not be less than £120,000. The chairman of the Moanataiari Company, at the last annual meeting of that company, made very sensible remarks in reference to prospecting the deep levels. He said he would like to see the mining companies combining to form a committee to draw up some scheme by which two important works—the extension of the Moanataiari tunnel and prospecting the deep levels—could be carried out. He earnestly impressed the gentlemen present to think the matter out, and devise a scheme, which could be taken to the Government to induce it to assist in the undertaking. He was quite convinced that until some sacrifice was made, and they could go to the Government with some scheme, nothing practical would be done in the matter. He thought that by companies assessing themselves to a certain amount they could get the Government to advance a certain sum of money. It would be difficult to tell what the future of the Thames Goldfield might be. He said he only threw out these suggestions, for unless something was done the Thames Goldfield would get from bad to worse.

There is no doubt something requires to be done, or else this portion of the Thames Goldfield, where the richest auriferous ore has been obtained in the colony, will in the course of a few years be virtually abandoned. There is still a good deal of gold to be found on the upper levels—that is, above the present drainage-level; but, with the exception of a few claims that may manage to carry on operations for a considerable time, some of the others are bound to succumb, and even those that are left may find that the drainage rates become too heavy to allow them to carry on their operations at a profit. Were it not for the heavy expense of drainage, no doubt companies would be able to carry on for a much greater length of time. Therefore, looking at the question of deep-level workings in all its phases, the ground below the 500ft. level is practically of no value to its present owners, as they cannot work it, and, in the interests of the goldfield, should be given up, in order to give inducements to outside capitalists to come in and assist in opening up the lower ground and prospecting the deep levels; and in consideration of this the company holding the deep ground may be asked to drain the upper levels of those companies who have given up the ground free of charge. Such an arrangement would make the claims of the present proprietors of considerably more value, and allow them to be worked for a much longer time than they can under the present system.

The other portion of the field where deep-level prospecting can be carried on is from the Moanataiari adit-level going on from Point Russell, about 30ft. above sea-level. This adit-level is constructed in a straight line into the hill for a distance of about 3,100ft., and, having cut through the Moanataiari slide, and at the end of the field where the gold-bearing band of country is nearest the surface, it would cut the country at the back, getting into probably the same strata of country that would be cut at the Queen of Beauty shaft, at about from 1,000ft. to 1,200ft. deep; but in getting on to the back into the range there is a possibility that it might get through the auriferous band or belt of country. If the extension of this adit-level were carried on in a straight line it would go through the Fame and Fortune and back into the range, where very few claims have been worked; but, if it were deviated a little to the northward, it would cut through the Golden Age, Reuben Parr, Orlando, Watchman, Star of the South, Sons of Freedom, Dixon's, and other reefs. Before anything could be done in this direction, an arrangement would have to be made with the Moanataiari Company for permission to use this adit-level, and to settle the terms and conditions on which future haulage would be done. Application was made to the department to subsidise the extension of this adit, but, before even this could be entertained, the owners of the claim it would go through would have to be arranged with, or else it would have to be made a public highway for the field, and placed under the management of trustees; and, if such were done, the Moanataiari Company would have a good claim for the cost of construction, which would amount to a large sum.

To prospect the deep levels on the Thames Goldfield by any means will entail a considerable amount of capital; and, before that capital can be got, a scheme will have to be proposed by which it can be shown that there is a fair probability of the money being returned. It cannot be expected that the Government will advance or grant the whole of the money required to test the deep levels on either this or any other goldfield.

The returns from the Thames Goldfield last year, notwithstanding the cry of depression, show that there has been an increase in the yield of gold for the year ending the 31st March, 1894, of about 3,300oz. 19dwt., as will be seen from the following comparative statement:—

Locality.	1893-94.						1892-93.					Gold Increase.	
	Number of Wages-men and Tributers employed.	Tons of Quartz crushed.	Tons of Mullock crushed.	Yield of Gold.	Gold from Tailings.	No of Tons Tailings treated.	Number of Wages-men and Tributers employed.	Tons of Quartz crushed.	Tons of Mullock crushed.	Yield of Gold.	Gold from Tailings.	1893-94.	1892-93.
				Oz. dwt.	Oz. dwt.					Oz. dwt.	Oz. dwt.	Oz. dwt.	Oz. dwt.
Tapu ..	13	150·5	..	201 18	..	..	10	36	176	246 7	..	..	44 9
Waiomo ..	1	0·4	..	143 9	..	..	..	..	..	..	..	143 9	..
Puru ..	5	137·9	..	37 9	..	..	..	..	..	..	..	37 9	..
Tararu ..	17	378·0	..	291 12	..	..	38	4,220	..	529 7	839 0	..	1,076 15
Shellback ..	5	26·0	..	33 4	..	..	11	144	..	151 19	..	..	118 15
Kuranui ..	62	8,400·5	3,450	4,202 9	..	..	75	2,654	13,173	3,804 19	..	397 10	..
Moanataiari	200	13,222·6	11,520	12,624 19	..	..	221	19,822	6,257	10,070 6	..	2,554 13	..
Grahamstown	36	708·0	..	617 5	2,411 4	13,220	57	588	1,000	816 9	..	2,212 0	..
Waiotahi ..	103	4,621·0	..	5,640 2	..	..	125	6,313	500	7,162 1	..	..	1,521 19
Waio-Karaka	107	3,984·0	..	4,916 14	..	..	23	867	..	546 4	..	4,370 10	..
Karaka ..	43	1,180·7	..	1,744 10	..	..	45	1,700	..	1,643 1	..	101 9	..
Una Hill and Te Papa	41	1,006·6	..	1,293 3	..	..	41	825	..	1,214 9	..	78 14	..
Hape Creek..	14	338·2	..	274 3	..	..	25	868	..	575 10	..	..	301 7
Puriri ..	..	..	..	..	..	..	2	44	..	31 10	..	..	31 10
Otanui ..	4	10·0	..	5 6	..	..	..	..	..	..	..	5 6	..
Matatoke ..	..	11·0	..	2 8	..	..	..	..	..	..	..	2 8	..
Tairua ..	7	71·1	..	179 14	..	..	3	45	..	65 0	..	114 14	..
Ohui ..	2	8·0	..	17 10	..	..	..	..	..	..	..	17 10	..
Tailings ..	..	..	..	..	..	..	184	..	..	..	4,478 12	..	4,478 12
Totals..	660	34,254·5	14,970	32,225 15	2,411 4	13,220	676	38,131	21,106	26,857 2	5,317 12	10,035 12	7,573 7

It will be seen from the above table that the total yield of gold from the Thames District last year was 34,636oz. 19dwt., whereas for the previous year it only amounted to 31,336oz., exclusive in both years of the gold obtained from tailings. The total quantity of quartz crushed last year was 34,254 tons, and 14,970 tons of mullock, while in the previous year there were 38,131 tons of quartz and 21,106 tons of mullock crushed: making a total of 78,546 tons of stuff, which yielded 31,336oz. gold. The total material operated on last year was 62,444 tons, which yielded 34,637oz. gold. Taking the number of men employed in the mines, there were sixteen less last year than in the previous one; but the estimated value of the gold and bullion obtained was £6,650 more than for the year 1892–93. Therefore, taking the number of men employed, and the value of the gold obtained—namely, £92,650—it gives an average of about £140 7s. 6d. per annum, or £2 14s. a week for each man at work; whereas the average earnings of the men on the same basis for the previous year was about £114 4s. 6d. a man per annum, or £2 5s. 6d. per week. It will be seen, therefore, that by taking the value of the gold obtained, and the number of men employed, it gives an average of 9s. 6d. a week per man more last year than it did for the previous year. In some portions of the district there has been a falling-off in the yield of gold, but in others it has increased.

Tapu.

The principal claims at Tapu are Sheridan's, the Fluke, and Centennial. There are thirteen men employed in the claims in this locality, and during last year about 150 tons of quartz was crushed, which yielded 201oz. 18dwt. gold; whereas during the previous year 35 tons of quartz and 176 tons of mullock were treated, which yielded 246oz. 7dwt. gold; and only ten men employed in the mines. Some very rich quartz has been obtained in this locality, but the most of the gold is got from small leaders; but, so far, the rich stone does not continue down for any great depth. At the Fluke Mine, F. McMahon and party crushed 42 tons of quartz, which yielded 128oz. 10dwt. gold. They are working on three different leaders, varying from 8in. to 1ft. 6in. in thickness; but this party is back for about four miles from the flat, and have to pack the quartz out for some distance before it can be carted to the battery. It is the intention of the party to try and form the claim into a limited company, in order to get sufficient capital to erect a crushing battery near the claim. In the Centennial Claim the surface mullock and clay was sluiced, and, from the quartz which was got from this mullock, 5½ tons, after being crushed, yielded 19oz. 15dwt. gold. The owners, however, do not consider the ground payable by working it by this method, and have abandoned it.

Waiomo.

There is very little work being done in this locality. A deal of the ore is of such a refractory character that the present methods of treatment fail to extract a fair percentage of its assay value. The owners of the Golden Gem and Monowai Claims are said to be in treaty with some one in Europe with the view of getting a satisfactory method of treating the ore, and, in the meantime, protection has been granted for the ground for a period to enable them to do this. A claim has been taken up near the Golden Gem ground by A. M. McMahon; and he reports that from the surface workings he had 7cwt. of quartz crushed last year, which yielded 143oz. 9dwt. gold.

Tararu.

The stoppage of the Sylvia Mine has considerably reduced the produce of gold from this locality. The company who owned the property could not find ore of sufficient value to pay for working, and, after having suspended operations for some time, the property was seized under writ and sold to Messrs. Darrow and party for £600. At the time the company suspended operations it was engaged in driving a low-level tunnel; but, whether from the want of capital, or the risks they were running in chancing to get payable stone at a lower level, the present proprietors have done no work in the mine. They now intend to surrender the ground, and sell the whole of the valuable plant and aërial tramway which connected the mine with the crushing-battery.

The principal mines in the locality of Tararu are the Norfolk, City of Dunedin, and Seddon. In the former mine the ore is of a very refractory character, but some of it is very rich. During the last year, from a crushing of 43 tons of quartz 147oz. gold was obtained. The returns from the City of Dunedin Mine has been very small; from 180 tons of quartz only 15oz. 12dwt. gold was obtained. The mine is now let on tribute. In the Seddon Mine the owners are working on three lodes: 3ft., 1ft. 6in., and 1ft. in thickness, respectively. So far, the work done in this mine has been of a prospecting nature. The ground is situate 1,500ft. above sea-level, which makes it expensive to take the quartz down to the flat to be crushed. About 1½ tons of stone was crushed at the Cambria battery, which yielded 4oz. 10dwt. gold; beyond this, all other tests have been made with the pestle and mortar. About 260ft. has been driven on the lode and a winze put down from the surface for about 40ft. The owners considered the results of testing the stone to be sufficient inducement for them to erect a small crushing-battery, as near the claim as possible, which they have made arrangements to do.

Kuranui.

The Kuranui Hill is full of veins and stringers of quartz, which all contain less or more gold. It is the place where rich auriferous stone was first discovered on the Thames field by Hunt and party, who are said to have got about £70,000 each out of the Shotover Claim. The rich stone in this locality was found near the surface; and since the Shotover Claim was given up, as worked out, by the prospectors, a large quantity of gold has been obtained, and at the present time Messrs. Hansen and Comer still continue to get stone of a payable character; and the Hazelbank Company, who hold the other ground in this locality, has, during the last year, done fairly well.

Hansen's Claim.—This claim is worked on the co-operative principle, there being fifteen shareholders and four wages-men. During last year the workings were confined to quartz taken from old stopes and stringers in the walls. This was considered more profitable than crushing the mullock from the face of the hill, which was done in previous years. The quantity of quartz crushed last year was 5,992 tons, and this yielded 1,079oz. 15dwt. of gold.

Comer's Claim.—The principal work in this claim was confined to working the surface stringers and veins of quartz, also the mullock from the face of the hill. Of the latter material, 3,450 tons were crushed, which yielded 262oz. 14dwt. of gold, being an average of 1·52dwt. of gold per ton; and from 190 tons of quartz, 190oz. 17dwt. of gold was obtained. This has not been a profitable investment for the owner last year. If the mine is to be carried on, it must be made to pay the expense of working. There is no getting away from the fact that, if the capital invested in mining is lost, the time will come when it will be an extremely difficult matter to get those with any money at their command to assist in developing mines; and, as a rule, the working miners have not sufficient means to open up mines so as to carry on large operations. Capital and labour must go hand in hand, and mines will have to be worked on the co-operative principle—both the capitalist and miner getting a fair division of the profits. Mr. Comer intends to work his mine on this system in future.

Hazelbank Company.—The ground that this company is working was known in the early days as the famous Caledonian Claim, from which gold was got which enabled dividends to be paid to the shareholders in one year to the extent of £650,000. According to the annual balance-sheet of the company for the year ending on 30th September last, 960 loads of quartz was crushed, which yielded 2,514oz. 16dwt. gold, having a value of £6,782 15s. 2d.; and money received in same period from tributers, £7 15s. 5d., making the total receipts £6,880 10s. 7d.; while the expenditure for the same period was £5,339 9s. 1d.: thus leaving a balance of £1,542 1s. 6d. as profit on the operations for the year. The capital of the company is £10,500, of which £5,775 is still uncalled up, thus leaving the actual capital invested to be £4,725. The profit on the year's transactions is therefore equal to about 32 per cent. on the paid-up capital. Taking the number of loads of quartz crushed, namely 960, which is equal to about 1,440 tons, the yield was equal to £4 14s. 2d. per ton; while the the cost of mining and crushing, including all expenditure, was about £3 14s. per ton. Taking the year ending the 30th March last, 2,218 tons of quartz was crushed, which yielded 2,669oz. 3dwt. gold, out of which £2,100 was paid in dividends.

Moanataiari.

In this locality there are a large number of men employed, the principal claims being the Junction, Alfred, Freedom, Orlando, Calliope, New Whau, New Alburnia, Dixon's Extended, New Chum, Caliban, and the New Moanataiari. The quantity of quartz crushed last year from this locality was 6,459½ tons, and 1,150 tons mullock obtained by wages-men, which yielded 8,870oz. 2dwt. gold; and 6,763 tons of quartz was obtained by tributers, which yielded 3,754oz. 17dwt. gold; making a total of 13,222½ tons of quartz and 11,520 tons of mullock crushed, yielding 12,624oz. 19dwt. gold; which was obtained by 110 wages-men and 90 tributers. This gives an average of 63·12oz. gold per annum for every man employed; but as the value of the gold in this locality would not exceed, taking the average, £2 15s. per ounce, the average per man for last year would be about £173 10s. The two principal mines are the New Moanataiari and the New Alburnia. In the former about 111 men, and in the latter 33 men, are employed, leaving 54 men who are employed in the other claims.

New Moanataiari Company.—This company may be said to be one of the largest employers of labour on the Thames field, and since its formation there have not been sufficient profits on the working to pay any interest on the capital actually invested, which is £12,477 10s. During the last five years, ending the 31st of October last, it has expended no less a sum than £32,200 in wages alone. There are still large blocks of ground left in this mine, above the main adit-level at Point Russell, where very little prospecting has been done, and where some rich finds may yet probably be got. There are also some large lodes running through the ground, which have proved to be of very low grade, so far as they have been tested, near the level of the new main adit.

The mine has so far, since the formation of the new company, been too good to abandon and too poor to pay for working. Calls have been occasionally made to carry on operations. The returns show that there is still a large quantity of gold in the ground, but the expense in obtaining it is greater than its value. During the year ending the 31st October last, 6,780 tons of quartz was crushed, which yielded 2,805 ounces of gold, having a value, including that got from tailings, of £9,152 3s. 3d., which is equal to £1 7s. per ton. There were also 11,283 tons of surface material treated, which yielded 685oz. 15dwt. gold. This gave the average value of the material treated 3s. 2d. per ton; yet this low yield left a profit on the workings of £257. In addition to this, 2,629 tons of quartz was obtained by tributers, which yielded 1,448oz. gold; so that the total quantity of gold obtained for the year amounted to 4,938¾oz. The value of the total proceeds for the year, including percentage from tributes and amount received for public crushings, was £10,716 11s. 1d., while the expenditure amounted to £11,135 6s. 3d., which shows a loss of £418 15s. 2d. on the year's operations.

This company has a valuable asset in the Point Russell adit-level, which is the key to the back country in this locality. This adit, constructed for about 3,200ft., is of sufficient width to admit of a double line of rails being used, and high enough to allow haulage by horses; and, were this adit-level extended, it would give greater facilities to other companies who hold ground further back into the hill to work their mines more economically.

Taking the year ending the 31st March last, 13,222½ tons of quartz were crushed, which yielded, in conjunction with 11,520 tons of mullock, 12,624oz. 19dwt. gold.

New Alburnia Company.—This company's mine is at a high level above the flat, and, consequently, it becomes expensive to get the quartz taken to the crushing-battery. Latterly they have been making arrangements with the owners of Dixon's battery to purchase it. The company then intend to extend the Ballarat and Chum's adit to a point where a shaft will be sunk on Punga Flat, where levels will be driven from, and the quartz will be put down this shaft and conveyed along the adit level to the mouth, where it will be carried by an aërial tramway to the battery, at an expense not exceeding 8d. per ton. During last year 1,800 tons of quartz were obtained by wages-men, which yielded 5,856oz. gold; and 285 tons by tributers, which yielded 135oz. 15dwt. of gold. Out of this the company paid the sum of £7,500 in dividends. The ore is partially of a refractory character. According to the tests made in 1892–93 by Mr. Park, of the School of Mines, only about 51 per cent. of the bullion was being saved by the ordinary battery process.

Grahamstown.

The principal mine being worked in this locality is the Victoria, but, so far, payable returns cannot be said to have been got. A good deal of prospecting has been carried on with only partial success. The mine is being worked from the shaft sunk by the Tookey Company. From the 160ft. level several lodes and leaders have been worked on, and, during the last year, 310 tons of quartz were obtained by wages-men, which yielded 352oz. 10dwt. gold; and 198 tons were obtained by tributers, wich produced 130oz. gold. About twelve men were employed in other claims, who obtained 200 tons of quartz, which yielded 134oz. 15dwt. gold; and 13,220 tons of tailings were treated, for a result of 2,411oz. gold.

Waiotahi.

The principal claims in this locality are the Waiotahi, Cambria, and Fame and Fortune. The former has been a dividend-paying claim for a large number of years. Last year there were 2,137 tons of stone crushed, which were obtained by wages-men, and 70 tons by tributers, which produced 2,718oz. 11dwt. gold, out of which £750 was paid in dividends to the shareholders. It is one of the mines on the field where the directors never interfere with the manager; and the result is that, when he finds any rich body of ore, instead of putting on a large number of men to work on the good stone, he keeps always prospecting works going ahead, so that by the time one place is worked out he has a fresh body of ore opened up to keep the crushing-battery at work. It may be said to be the only mine on the Thames where prospecting operations and dead-work is sytematically carried on. If the principle of only operating on the rich bodies of ore met with from time to time had been adhered to, this mine would probably have been abandoned years ago. Either a mine has to be worked on the principle adopted at the Waiotahi, or each company should carry a percentage of its profits to a reserve fund, to carry on prospecting operations as the different levels are stoped out.

Cambria Company.—This company is working similar ground to that worked by the Waiotahi Company. A large portion of the gold is obtained from small stringers or leaders; but, taking the operations of the company for the last year, they have not been remunerative. According to the last annual balance-sheet, for the year ending 14th December last, 1,131 loads (1696 tons) of quartz were crushed, which yielded 1,516oz. 3dwts. gold, having a value of £4,202 9s. 5d. The receipts from public crushings amounted to £1,545 16s. 8d., and from sundry other sources £30 1s. 0d., making a total of £5,778 7s. 1d.; while the expenditure for the same period amounted to £5,859 9s. 2d. Out of this expenditure, £2,032 5s. 1d. is charged against the crushing-battery, and £3,927 4s. 1d. against the working of the mine. This shows that the cost of working the crushing-battery was £486 8s. 5d. more than that received for public crushing, and that the actual expenditure on mine

and crushing-battery, in connection with the 1,696 tons of quartz, was equal to about £2 12s. per ton, while the value of the gold obtained was about £2 9s. 6d. per ton. Taking the year ending the 31st March last, 1,621 tons of quartz have been crushed, which yielded 1,469oz. 17dwt. gold, while thirty wages-men have been employed.

Fame and Fortune.—This mine has been principally worked during last year by tributers. There were seven wages-men employed, who obtained 50 tons of quartz, which yielded 48oz. 9dwt. gold; and twelve tributers, who got 338 tons of stone, which produced 799oz. gold. This mine was formerly the property of an English syndicate, under the superintendence of Mr. Kersey Cooper, but it is said to have been sold to an English company, having a capital of £50,000, during last year, and it is intended to carry on mining operations in the future on a larger scale.

There are several other claims in this locality, where eighteen wages-men and four tributers are employed, and from which 399 tons of quartz have been obtained, yielding 604oz. 3dwt. gold.

Waiokaraka.

The principal claims in this locality are the May Queen, The St. Hippo, and Queen of Beauty. Formerly there were a large number of men employed in this part of the field, but some of the ground has now been pretty well stoped out to the lowest level that drainage can be effected. There is, however, a large area of ground yet to work, if the gold continues down in the lodes that can be taken out with the present drainage appliances. At the same time, good stone is found under-foot in the deepest level, which cannot be worked until other provision is made for getting clear of the water to the drainage-shaft.

May Queen Company.—This company now holds the claim formerly known as the May Queen, Trenton, Saxon, and Queen of May. Their balance-sheet for the year ending the 20th of February last states, that 1,770 loads—2,655 tons—of quartz was crushed which yielded 2,395oz. 6dwt. of gold, the value of which, including tribute percentage and tailings, amounted to £7,178 10s. 2d.; and the receipts for public crushing and battery amounted to £233 9s. 8d., making a total of £7,411 19s. 10d.; while the expenditure in connection with the mine and battery charges was £7,261 15s. 6d., which shows a profit of £150 4s. 4d. on the year's operations. The capital of the company is £39,500, of which £4,608 6s. 8d. is paid up. The profit on the actual workings, though small, is equal to 3½ per cent. on the paid-up capital. Taking the year ending 31st March, there was 3,558 tons of quartz crushed, which yielded 4,369oz. 11dwt. gold; while the number of wages-men employed was thirty, and fifty-seven tributers.

The ground in the Saxon is worked down to the greatest depth that the present drainage-level admits of. All the workings are between the 400ft. level and the surface. The company intend to continue the No 6 level of the Saxon into the Queen of May section. The distance that this will have to be extended to the Queen of May shaft is about 1,361ft., it will therefore take a considerable time before communication can be effected.

St. Hippo.—This was formerly known as Crawford's Special Claim; the workings are now carried from the low-level adit. During last year this adit has been extended on the lode for a distance of 182ft., and stoping carried on above this level. Fourteen wages-men have been employed during the past year, who have obtained 328 tons of quartz, which yielded 484oz. 5dwt. gold.

Queen of Beauty.—This claim has only been worked by a few men during a portion of the year. At present the ground is protected, with the view of affording the owner an opportunity of forming a company with sufficient capital to work the mine systematically. A good shaft has been sunk on this claim to a depth of 748ft. For the first 350ft. the pump portion is 6ft. by 6ft., and the winding portion 6ft. 6in. by 3ft. 6in.; below this the shaft is framed 6ft. by 12ft. 6in. in the clear, so that it is a very useful shaft to work from; but, as the upper portion of the lodes are all pretty well stoped out to the 660ft. level, it will require a considerable capital to continue operations. During the last year 73 tons of stone was got on the upper levels, which yielded 42oz. 17dwt. gold.

Karaka.

In this portion of the Thames field there were twenty-three wages-men and twenty tributers employed; the wages-men obtained about 760 tons of quartz, which yielded 1,338oz. 19dwt. gold; and the tributers got 421 tons which produced 405oz. 11dwt. gold. The highest yield was from the Claremont Claim, where 37½ tons yielded 973oz. 19dwt. gold. The principal claims in this locality are the Adelaide, Claremont, Lone Hand, Onehunga, Karaka, and Ophir, but there is nothing specially to mention with regard to any of them.

Una Hill and Te Papa.

The principal claims in this portion of the field are the Occidental, Pride of Karaka, Magnolia, Homeward Bound, and North Star. There are seventeen wages-men and twenty-four tributers employed in the claims. The wages-men obtained 516½ tons of quartz, which produced 797oz. 10dwt. gold; and the tributers got 490 tons of stone, which yielded 495oz. 13dwt. gold. The largest return from any of these claims for the number of men employed was in the North Star, where four wages-men obtained 300 tons of quartz, which yielded 323oz. 4dwt. gold.

The following statement will show the areas held by each company and owner of mines on the Thames field, together with the number of wages-men and tributers employed in each claim; the number of tons of quartz crushed, and the yield of gold therefrom, the value of which is estimated at £92,650.

STATEMENT of GOLD RETURN for the HAURAKI DISTRICT for Year ended 31st March, 1894.

Locality and Name of Mine.	Area.	Average Number of Men employed.		For Owners.				For Tributers.		Tailings.	
		Wages-men or Owners.	Tributers.	Quartz crushed.	Gold obtained.	Mullock.	Gold obtained.	Quartz crushed.	Gold obtained.	Quantity treated.	Gold obtained.
Thames County.	A. R. P.			Tons cwt. lb.	Oz. dwt.	Tons.	Oz. dwt.	Tons cwt. lb.	Oz. dwt.	Tons.	Oz. dwt.
Tapu—											
Sheridan's ..	20 3 4	4	..	13 0 0	33 0	..	..	..	..	..	..
Fluke	20 2 16	4	..	42 0 0	128 10	..	..	..	..	..	..
Centennial ..	10 0 0	2	..	5 10 0	19 15	..	..	..	..	..	..
Sundries	10 0 0	3	..	90 0 0	20 13	..	..	..	..	..	..
	61 1 20	13	..	150 10 0	201 18	..	..	..	..	..	..
Waiomo—											
Young Colonial ..	1 0 0	1	..	0 7 0	143 9	..	..	..	..	..	..
Puru—											
Tetley's Claim ..	10 0 0	3	..	136 0 0	21 6	..	..	..	..	..	..
Campbell's Claim ..	5 0 0	1	..	1 0 0	8 12	..	..	..	..	..	..
Tui Claim.. ..	3 0 0	1	..	0 18 0	7 11	..	..	..	..	..	..
	18 0 0	5	..	137 18 0	37 9	..	..	..	..	..	..
Tararu—											
Norfolk	30 0 0	6	..	43 0 0	147 0	..	..	..	..	..	..
Sylvia	179 3 0	..	..	120 0 0	92 0	..	..	..	..	..	..
City of Dunedin ..	26 2 0	2	..	180 0 0	15 12	..	..	..	..	..	..
Seddon	30 0 0	6	..	1 10 5	4 10	..	..	..	..	..	..
Sundries	..	3	..	33 10 0	32 10	..	..	..	..	..	..
	266 1 0	17	..	378 0 5	291 12	..	..	..	..	..	..
Shellback—											
Nordenfeldt ..	15 3 31	2	..	12 0 0	10 0	..	..	..	..	..	..
Sundries	..	3	..	14 0 0	23 4	..	..	..	..	..	..
	15 3 31	5	..	26 0 0	33 4	..	..	..	..	..	..
Kuranui—											
Hansen's	14 3 10	4	15	..	..	..	....	5,992 10 0	1,079 15	..	..
Comer's	13 1 37	9	6	..	..	3,450	264 14	190 0 0	190 17	..	..
Hazelbank ..	16 1 23	28	..	1,808 0 0	2,613 16	..	..	410 0 0	55 7	..	..
	44 2 30	41	21	1,808 0 0	2,613 16	3,450	264 14	6,592 10 0	1,325 19	..	..
Moanataiari—											
Moanataiari ..	94 3 26	58	53	4,728 0 0	1,841 8	11,520	705 7	3,358 10 0	2,039 10	..	..
Junction	15 0 0	2	2	..	..	..	..	2 0 0	1 3	..	..
Alfred	10 0 5	..	6	..	..	..	..	286 10 0	285 6	..	..
Freedom	6 1 10	..	2	..	..	..	..	73 0 7	24 12	..	..
Orlando	15 0 0	7	4	34 0 0	88 19	..	..	150 0 0	43 18	..	..
Calliope	10 3 0	4	4	..	..	..	..	100 0 0	150 0	..	..
New Whau ..	3 2 8	4	6	80 0 0	93 0	..	..	1,300 0 0	710 0	..	..
New Alburnia ..	15 1 0	28	5	1,800 0 0	5,856 0	..	..	205 0 0	135 15	..	..
Dixon's Extended ..	3 2 18	..	7	..	..	..	..	1,283 0 0	347 13	..	..
New Chum ..	5 0 0	2	..	9 1 50	97 2	..	..	..	..	..	..
Caliban	7 0 27	2	1	58 0 0	11 17	..	..	5 0 0	17 0	..	..
Sundries	20 0 0	3	..	200 10 15	176 9	..	..	..	..	..	..
	206 2 14	110	90	6,459 11 65	8,164 15	11,520	705 7	6,763 0 7	3,754 17	..	..
Grahamstown—											
Victoria	34 1 30	14	10	310 0 0	352 10	..	..	198 0 0	130 0	..	..
Sundries	..	12	..	200 0 0	134 15	..	..	..	..	13,220	2,411 4
	34 1 30	26	10	510 0 0	487 5	..	..	198 0 0	130 0	13,220	2,411 4
Waiotahi—											
Waiotahi	23 0 10	30	2	2,137 0 0	2,667 16	..	..	70 0 0	50 15	..	..
Cambria	15 2 17	30	..	1,621 0 0	1,469 17	..	..	..	..	..	..
Fame and Fortune..	55 0 11	7	12	56 0 0	48 9	..	..	338 0 0	799 0	..	..
West Coast ..	6 1 0	..	2	..	..	..	..	42 0 44	78 14	..	..
New Fearnought ..	11 1 13	2	..	58 0 0	91 8	..	..	..	..	..	..
Acme	19 3 10	4	2	..	..	..	..	5 0 0	88 15	..	..
Sundries	30 0 0	12	..	294 0 0	345 8	..	..	..	..	..	..
	161 0 21	85	18	4,166 0 0	4,622 18	..	..	455 0 44	1,017 4	..	..

STATEMENT of GOLD RETURN, HAURAKI DISTRICT—*continued.*

Locality and Name of Mine.	Area.	Average Number of Men employed.		For Owners.			For Tributers.		Tailings.	
		Wages-men or Owners.	Tributers.	Quartz crushed.	Gold obtained.	Mullock. Gold obtained.	Quartz crushed.	Gold obtained.	Quantity treated.	Gold obtained.
Thames County—con.	A. R. P.			Tons cwt. lb.	Oz. dwt.	Tons. oz. dwt.	Tons cwt. lb.	Oz. dwt.	Tons.	Oz. dwt.
Waiokaraka—										
May Queen ..	71 0 0	30	30	3,230 0 0	3,139 0	.. ..	328 0 0	1,230 11	..	..
St. Hippo	78 0 0	14	..	328 0 0	484 5	.. ..	..	..	..	..
Queen of Beauty ..	47 0 0	..	..	16 0 0	18 10	.. ..	57 0 0	24 8	..	..
Sundries	..	3	7	25 0 0	20 0	.. ..	..	..	..	..
	196 0 0	47	56	3,599 0 0	3,661 15	.. ..	385 0 0	1,254 19	..	..
Karaka—										
Adelaide	12 0 30	..	..	..	..	.. ..	112 0 0	89 0	..	..
Claremont ..	1 0 0	1	..	7 10 44	779 7	.. ..	2 0 30	14 12	..	..
Lone Hand ..	49 2 10	4	14	17 0 0	80 15	.. ..	307 0 0	301 19	..	..
Onehunga ..	10 0 0	2	..	29 0 0	36 15	.. ..	..	..	..	..
Karaka	10 0 0	5	..	473 0 0	114 14	.. ..	..	..	..	..
Ophir	10 0 0	5	..	93 10 34	71 13	.. ..	..	..	..	..
Sundries	..	6	..	139 13 20	255 15	.. ..	..	..	..	..
	92 3 0	23	20	759 13 98	1,338 19	.. ..	421 0 30	405 11	..	..
Una Hill and Te Papa—										
Occidental ..	21 0 9	2	10	..	..	.. ..	124 0 0	264 8	..	..
Pride of Karaka ..	14 3 24	1	4	25 0 0	60 4	.. ..	114 0 0	127 0	..	..
Magnolia	17 2 30	2	6	..	..	.. ..	252 0 0	104 5	..	..
Homeward Bound ..	3 0 22	5	..	122 1 15	357 19	.. ..	..	..	..	..
North Star ..	30 0 0	4	4	300 0 0	323 4	.. ..	..	..	..	..
Just-in-Time ..	5 0 0	1	..	17 10 0	3 12	.. ..	..	..	..	..
Sundries	..	2	..	52 0 0	52 11	.. ..	..	..	..	..
	91 3 5	17	24	516 11 15	797 10	.. ..	490 0 0	495 13	..	..
Hape Creek—										
Consols	29 3 31	..	6	..	..	.. ..	255 0 0	157 5	..	..
Waymouth ..	3 0 0	2	..	7 4 0	31 2	.. ..	..	..	..	..
Sundries	20 0 0	6	..	76 0 86	85 16	.. ..	..	..	..	..
	52 3 31	8	6	83 4 86	116 18	.. ..	255 0 0	157 5	..	..
Otanui—										
Alpine	30 0 0	..	4	10 0 0	5 6	.. ..	..	..	..	..
Matatoke—										
Teddy's	10 0 0	..	..	11 0 90	2 8	.. ..	..	..	..	..
Tairua—										
Bonnie Scotland ..	5 0 0	2	..	57 0 0	110 14	.. ..	..	..	..	..
Gentle Shepherd ..	5 0 0	1	..	2 0 0	10 10	.. ..	..	..	..	..
McLiver Bros. ..	5 0 0	1	..	1 2 0	11 10	.. ..	..	..	..	..
Tairua River—										
Davis's New Find ..	30 0 0	3	..	11 0 0	47 0	.. ..	..	..	..	..
	45 0 0	7	..	71 2 0	179 14	.. ..	..	..	..	..
Ohui—	30 0 0	2	..	8 0 0	17 10	.. ..	..	..	..	..
Totals* ..	1,357 3 22	407	253	18,694 19 23	22,716 6	14,970 968 1	15,559 10 81	8,541 8	13,220	2411 4

* Estimated value of gold, £92,650.

NOTE.—The areas shown do not include the whole of the land occupied, but only that from which the returns are derived.

Ohinemuri.

This is a district which promises to become one of considerable importance. Very little prospecting has yet been done in a large portion of this district; and very little is known respecting some of it, between Waitekauri and Whangamata. Karangahake was the first field opened up in the Ohinemuri District; but many years elapsed before any good payable ore was discovered. The same may be said with respect to the Waihi field. The very ground from which good returns are now being got was worked for eight years and hardly paid the expense of working; and the more recent discoveries made by Lowerie Brothers and Birney, at Waitekauri, show that very little prospecting in that locality had ever been done, as the lodes were found cropping out on the surface. During the past year 454 men have been employed in and about the mines. 28,572½ tons of ore have been crushed, which yielded 51,545oz. 15dwt. bullion. Of this amount, 14,774oz. was recovered by the cyanide process; and 2,700 tons of tailings were treated, which yielded 7,057oz. 8dwt. bullion. This makes the total return for the year 58,603oz. 3dwt., representing an approximate value of £107,000 15s.

Karangahake.

There are only two mines on this field where mining operations have been actively carried on during the past year—namely, the Crown and the Woodstock. There are two other claims—the Earl of Glasgow and Diamond—in which prospecting operations are being carried on, besides ten sundry parties who are working on the field. The total quantity of ore treated last year was 5,200 tons, which yielded 12,791oz. bullion.

Crown Company.—This company have now their plant at full work; and the ore, although not so rich as was at first anticipated, is of a highly payable character. The mine, which is situate in the gorge of the Waitawhita Creek, is well opened out, and shows that there is a large quantity of payable ore. The lode the company is working is what is known as the Welcome Reef, which has an average thickness of about 5ft. About 2,000ft. of levels have been constructed. Two cross-courses were met with in driving the levels, the first one being 460ft. in from the mouth of the adit and the next one at 530ft. These shifted the lode a little, but did not affect it in either thickness or value. The heave of the lode in the cross-courses is rather more at the upper level than what it is at the lower one, and the country at the lower level appears to be more of a settled nature than overhead.

Gold appears in the outcrop of the reef, which can be traced for 100ft. over No. 3 level. The lode on the level, as it gets into the hill, is somewhat broken and disturbed; but at 400ft. in from the mouth of the No. 4 level an uprise has been put up for 60ft., showing very good stone. This shows that the broken and disturbed country will not go very far down.

On the north side of the creek the outcrop of the reef continues to a much greater height than on the south side, and has been prospected at several levels with very satisfactory results, the character of the ore in the lode being somewhat similar from top to bottom. The country rock is of a hard and compact nature, which makes the construction of levels and uprises a slow undertaking when done by hand-drilling. The company are erecting a complete plant of rock-boring machinery, in order to carry on operations more expeditiously. This plant consists of a 40-horse power air-compressor and four rock-drills. The compressor is to be driven by a water-motor, and the water-supply used for working the old plant in the Waitawheta Gorge will be utilised for this machinery.

According to the company's balance-sheet of the 31st May, 1893, the capital of the company has been increased from £65,000 to £100,000 in 100,000 shares of £1 each, of which 75,770 shares are fully paid up, with the exception of £70 10s. arrears of calls.

Expenditure—	£	s.	d.
The purchase of the property cost	35,000	0	0
Value of paid-up shares given to the Cassel Company for patent-rights in connection with cyanide process	15,154	0	0
Reconstruction expenses	227	10	8
Value of plant acquired from old company	666	16	0
Removal and re-erection of plant, water-races, &c.	18,321	15	1
Value of stores on hand	549	3	7
Cash in bank	5,288	6	11
	£75,207	12	3

The results of working the mine for the year ending 31st May, 1893, were as follows: There was 226 tons of ore treated, which gave bullion to the value of £3,612 8s. 8d.; and the expenditure at the mine during the same period was £6,768 17s., and at the Home office £584 17s. 6d., making the total expenditure £7,353 14s. 6d.: thus showing a loss on the year's transactions of £3,741 5s. 10d.; but against this, 1,143 tons of ore had been got from the mine and stacked at the mouth of the adits, which would show that this ore was debited with a cost of about £3 5s. 5d. per ton.

The total quantity of ore treated at the old mill was 614 tons, which yielded bullion to the value of £8,270. The total quantity of ore treated up to the 13th March last was 4,674 tons, yielding bullion to the value of £27,318; deducting the quantity of stone crushed previously, and the value of the bullion, it would show that 4,060 tons has been crushed, and treated by the new plant, which yielded bullion, to the value of £19,048, which would give the average value of the ore to be about £4 14s. 3d. per ton. Taking the whole of the ore extracted from the mine, it gives an average value of about £5 16s. 11d. per ton. Taking the quantity of gold in the ore, which, according to assay, was 7,010oz., the quantity extracted was 6,603oz. or 94 per cent. The quantity of silver according to assay was 8,588oz., and the quantity extracted was 7,169oz., being 83·4 per cent.; by taking the assay value of the whole of the bullion, which was £29,007, and the value of that extracted, namely £27,318, it shows that a saving of 94 per cent. of the assay value has been obtained. The percentage of cyanide used for treatment was 0·12. Taking the year ending the 31st March last, there was 4,544 tons of ore crushed, and treated by the cyanide process, which yielded 11,130oz. 15dwt. of bullion; while the average number of men employed throughout the year was 112.

Woodstock Company.—There is some very good ore in this company's claim, but it has not yet been opened up on anything like a large scale. During the past year there has been sixteen wages-men and two tributers employed. The company have been carrying on the operations on their own behalf on No. 2 lode, which averages about 4ft. in thickness. This lode has been opened out at the No. 3 level, which is 150ft. below the ore above it, and about 250ft. above the bed of the Waitawheta Creek. The lode has been driven on for a distance of 150ft., carrying good ore for the whole of the way. A winze was sunk on this lode from the No. 2 level to a depth of 70ft., and it varied in thickness from 3ft. to 5ft., giving an average assay value of £6 per ton. There were 568 tons of ore treated for the company last year, which yielded 1,517oz. bullion; and 51 tons by tributers, which produced 71oz. bullion.

There were sixteen men employed in the other claims, principally carrying on prospecting operations. They had 29 tons of ore crushed, which gave a yield of 73oz. bullion. There is a number of auriferous and argentiferous lodes in the locality, and some very rich ore has been got from time to time. Some years ago, some of the ore from the Adeline Mine, which was forwarded to the Thames for treatment, yielded 10oz. of gold to the ton. The field only requires to be systematically prospected to open it up. The whole of the range between this and Waiorongomai is full of auriferous and argentiferous leaders and lodes, which will yet be found to give fair returns for working.

Owharoa.

There was some very rich stone got in this locality in former years, but latterly the mines have not given payable returns for working. During the past year six men and three tributers have been employed, with a result that 1,280 tons of ore have been crushed, which yielded 235oz. 10dwt. of gold.

Waitekauri.

This is a field to which we may look in the future, as being one where fresh developments will be made. During the last two years several new discoveries have been made, and some of these are proving profitable investments. Last year there has been an average of eighty-six men employed, and 2,428 tons of ore have been crushed, which yielded 10,758oz. of bullion.

Golden Cross Mine.—This mine is situated on one of the branches of the Waitekauri Creek, about five miles from the old crushing-battery at Waitekauri. The discovery was made by Messrs. Lowrie Bros., who sold it to Mr. T. H. Russell. When in this portion of the district, time would not permit me to visit this mine; but a report on the property which appeared in the *Auckland News* of the 27th January last will give a good idea of its value. The correspondent states:—

"By Mr. Russell adopting a systematic plan of operations, and the erection of a crushing-plant that its value was discovered. Lowrie's discovery was only a surface one, an intangible, uncontinuous mass of quartz in a face of what might or not prove to be a slip; but, tracing the lode along the surface, permanent operations were commenced in what appears to be the dried-up bed of an old watercourse, and here the lode which has since given such remarkable returns was opened up and driven on. It is a fine, compact, well-defined lode, averaging, for the 90ft. it has been worked on, a width of 8ft. No time was lost in erecting a small crushing-plant of five head of stampers, and a berdan; and, out of this block, although the stopes are only about 25ft. in height, 600 tons of ore have been taken, the crushing of which is now almost completed. With the battery process already alluded to, this ore has realised about £4,000; and the tailings, all of which have been saved, are estimated to be worth £6 a ton, or £3,600 more, making a total of £7,600, or over £12 a ton. This, it must be acknowledged, is a splendid yield from a new mine.

"But, perhaps, a brief reference to the route to the mine itself may be of interest. In company with Mr. Russell and Mr. James, manager of the Cassel Company's cyanide process, we rode up the valley in the direction of the mine. The grade is not very steep, and might be considerably improved; but the track is cut by the cartage of timber and mill-plant, and, being through dense forest, through which the sun with difficulty finds its way, there are some bogs into which the horses sink to their knees, making travelling slow and difficult; but, on arriving at the mine, we found operations in full swing at the battery and in the mine, and preparations in progress for the extension of the plant, the introduction of the dry crushing and cyanide process, and a new low-level started, to give 60ft. extra backs on the reef.

"It may be considered curious that greater depths of backs cannot readily be obtained; but the fact is, that the drive on the reef is on the lowest point of the prospectors' ground. As the reef, however, extends north and south, the ranges rise, and the depth of backs to be opened up by the new level will be very extensive. The original licensed holding, it may be mentioned, was 26 acres; but the judicious purchase of the Golden Gate licensed holding of 18 acres has greatly enhanced the value of the property, by giving not only increased depth, but the battery-site, as well as the site for the main adit. On the high ground to the right side of the creek is a very large reef, over 20ft. in width in places, and, whether this is a continuation of the reef now being worked or a parallel reef, as some think, it is a most important factor in the value of the mine, for the ore, which is very similar in appearance to that of the Silverton Reef, in Waihi, possessing all those wavy characteristics which figured in the best of that company's ore, and, although not so rich as the ore treated from the main workings, it is, Mr. Russell estimates, equal in value to the ore from the famous Martha Reef in Waihi, and, as this gold is found fully 600ft. north of the main workings, it proves conclusively that there is a long run of golden country to operate on in this direction alone, irrespective altogether of the large area still untried to the south of the present workings. Everything marks permanence, and the indications all round are excellent, for there is not a portion of the cap of the reef that does not, when tested, show gold.

"A new main level is now being driven by contract, and it is estimated that it will have to reach a distance of 700ft. before it strikes the reef diagonally, and for some time this will be the main level of the mine. It will come out somewhat under the battery level.

"As already stated, the present plant consists of five stampers and a berdan, the treatment being by the wet process; but a new plant of ten head of dry-crushing stampers, and a complete cyanide process, has been decided on; and the contractor, Mr. Lynch, was on the ground when we visited it, making the necessary arrangements for the extension of the buildings, the erection of the plant, and the construction of the cyanide vats. The roof of the existing building has to be raised 9ft., in order to afford elevation for the stone-breaker on top, from which the ore will gravitate to the stampers, until its treatment is completed in the percolation vats, and the zinc towers in which the gold and bullion are extracted. There will be two cylinder cyanide vats, each 22ft. in diameter, fixed in an extension of the building on the east side, and which will be 54ft. by 23ft. A further addition will be made to the south end of the present building, 20ft. by 20ft. This will

contain the air-chambers, solution vat, the zinc towers or boxes, the receiving tank and sumph. The force-pump and air-pump will be in the present building, and a 3in.-pipe will be used for sluicing out the vats and plant. It may be added that the timber for the buildings is all cut, and a portion of it on the ground, and a start has been made to clear the excavation for the foundations. The motive power is a Pelton wheel 6ft. in diameter, with 150ft. fall of water, delivered through a ⅞in.-nozzle, and not more than half the water is required for the present plant, so that there will be ample for the increased plant. The water is conveyed from the race through 850ft. of 10in. wrought-iron pipes, so that the work is a permanent one, which will not require renewing for many years to come. In fact, permanence has been kept in view in everything that has been done, and the main adit now being driven is no exception, for it is very high and wide, the intention being to use horses in it when required for trucking.

"A company has now been formed to carry on future operations, under the No-liability Act, in 24,000 £1 shares, fully paid up, and sufficient assets are being transferred to the company to complete the works now commenced, and to put in the low-level tunnel.

"The kilns are being excavated for roasting the ore before treatment. Of course, as the tunnel level is lower than the battery, the tramway from the mine will be considerably lower than the mouths of the kilns, and it will be therefore necessary to elevate the quartz to charge the kilns, as well as to again elevate the roasted ore from the outlet of the kilns to the stone-breaker on top of the plant; but, to meet these requirements, a hydraulic lift will be erected on the same principle as that at Waihi, which is most inexpensive, and which has already elevated some 15,000 tons of ore without showing the slightest sign of deterioration. Mr. W. H. Moore has charge of the mine and plant, and the success which he has already achieved under great difficulties shows that he is the right man in the right place."

The returns from this mine for the year ending the 31st March last show that 600 tons of ore was crushed, which yielded 1,632oz. gold.

Komata Company.—The return from this company's mine last year give fair results. From 1,708 tons of ore, 8,996oz. bullion was obtained, and 1,075 tons of tailings were treated by the cyanide process, which yielded 5,610oz. bullion. The total returns last year was, therefore, 10,071oz. bullion; and there was an average of thirty men employed about the mine and works. The principal mining operations which were carried on last year were from the No. 3, or low-level: on No. 1 lode, which is about 8ft. in thickness; and on No. 2 lode, which is about 6ft. in thickness. A winze has been sunk down from the low-level on No. 2 lode to a depth of 48ft., and a portion of the lode under the level is stoped out. This mine was originally purchased by Mr. T. H. Russell from the prospectors, but the property, including the crushing-battery and plant at Waitekauri, has since been purchased by a company.

Grace Darling Company.—This company's mine is situate on the spur leading down from the tramway which connects the Komata Mine with the crushing-battery. A considerable amount of prospecting has been done, and the mine opened out. The lode in the surface level is from 4ft. to 8ft. in thickness, and on No. 2 level the lode shows a thickness of about 7ft. Gold is seen freely in the stone; and the company are so satisfied with the prospects that it is erecting a crushing-battery of ten heads of stamps, and a cyanide-plant. It is intended to adopt dry crushing, which will necessitate drying-kilns to be made before crushing is commenced. It is expected that the plant will be completed by the end of June.

Waihi.

A good deal of attention has been directed to this portion of the Ohinemuri District since the purchase of the Martha Company's interest by the Waihi Gold and Silver Company. Previous to this it was looked on as a place where there were large lodes containing both gold and silver; but, as the average yield per ton of ore was very small, these lodes could not be worked at a profit. The Martha Company worked the Martha Lode from the surface downwards by simply quarrying it, for about eight years, and the average yield from the ore was just sufficient to pay working expenses, without returning any of the money that the shareholders had laid out in the erection of a crushing-plant, tramways, and opening-out the mine. After quarrying the lode down to such a depth as they considered safe to work, they constructed an adit-level, and drove on the lode for about 700ft., and stoped out what they then considered the best portion of the lode, when they sold the whole of the mine and plant to Mr. H. Russell for some £3,000, who afterwards sold it to the Waihi Gold and Silver Company for something like £20,000 in paid-up shares. Since this lode has been worked by the Waihi Company handsome returns have been obtained, instead of getting an average yield of from 4dwt. to 6dwt. of gold per ton, as was obtained by the Martha Company. The reason of this is solely due to the superior appliances for extracting the gold from the ore; but while the Waihi Company have extracted a larger percentage of the bullion from the ore than was done by the Martha Company, still the appliances they have formerly adopted only extracted about 65 per cent. of the gold, and about 35 per cent. of the silver; recently, however, they have erected a Cassel plant in connection with their battery, and are treating a portion of the pulverised ore in a solution of potassium cyanide; and a portion of it at the time of my visit was still being treated by pan-amalgamation.

It will be seen from this that, even with the superior appliances that the Waihi Company have been using, the percentage of bullion extracted is only very small. But what can be said of the appliances used by the Martha Company, who could only get about one-third of the bullion per ton of that obtained by the present company. This shows clearly the necessity of having ore carefully sampled and assayed, in order to ascertain its correct value. The natural sequence is that millmen who do not take the trouble to do this are under the impression that they are saving a fair percentage of the gold and silver, and that it is only time wasted, as well as extra expense, to carefully assay the ore. Had the Martha Company known the value of the ore in the lode, they would have found that, with the appliances they were using, they were not obtaining much above 20 per cent. of the bullion.

The Waihi Company erected a Cassel plant to treat only a portion of their pulverised ore, in order that they could test the different methods of treatment against each other. Therefore, by having the ore from 40-head of stamps treated by amalgamation, and the same ore from another battery of 30-head of stamps treated in a cyanide solution, a good comparison could be made. The result showed that, while by pan-amalgamation 65 per cent. of gold and 35 per cent. of silver was obtained, the ore treated by the cyanide solution yielded 90 per cent. of its gold and about 50 per cent. of its silver. That is, if the assay value of the ore showed it to contain 1oz. of gold and 4oz. silver to the ton, by adopting the cyanide process 18dwts. of gold and 2oz. silver is recovered; while, by pan-amalgamation, only 13dwts. of gold and 1oz. 8dwts. of silver is recovered: thus showing a saving in favour of the cyanide process of 5dwts. gold and 8dwts. of silver to the ton, less the extra expense of treatment and royalty to the Cassel Company.

Many experiments have been made by this company, in regard to the treatment of the ore, with the view of ascertaining the cheapest and most economical methods to adopt. Dry crushing is now strictly adhered to. It was considered at one time that the tear and wear was far greater by dry crushing than by wet, while the quantity of pulverised ore was less. Experiments were made by having 30 heads of stamps crushing dry, and the same number of stamps crushing wet. The result of this was that the quantity of ore pulverised was slightly more by wet crushing, but the amount of slimes was also considerably more, and also the amount of bullion by pan-amalgamation was less than that obtained from the ore that was crushed dry. After several months' trial by the two systems the wet crushing was abandoned, and at the present the whole of the sixty heads of stamps is crushing the ore in a dry state. In a conversation with the manager, Mr. Barry, as to the advantages and disadvantages of dry crushing, he stated that, although the wear-and-tear on the bearings in a dry-stamp mill may be slightly more than when the ore is crushed wet, still the wear-and-tear of shoes, dies, screens, and mortars is considerably less by adopting dry crushing. When this mill was first erected dry crushing raised a considerable quantity of dust in the air within the building, but by means of ventilation and dust-chambers the air inside the building is now rendered comparatively pure to what it was at first.

In my previous reports, attention was directed to the mode of drying the ore, and the waste of heat in the open kilns which were then used. They were made in the shape of an inverted cone, having a hole in the bottom, from which the ore was drawn out when dried, and the kiln emptied ready for another charge. The company have now constructed much larger kilns, which are 20ft. in diameter at the top and 37ft. in depth, capable of holding 100 tons of ore. These kilns are not emptied after every charge, but every third day about 50 tons are drawn out, and a similar quantity of wet ore and firewood added on to the top of the charge. By this means the kilns are never allowed to get cold, and there is always sufficient heat below to set fire to the firewood, which is added and mixed with the new charge of ore. With these kilns the ore is dried more cheaply than previously.

In reference to the process of treating the ore by the Cassel process at this company's works, the manager (Mr. Barry) states: "The ore is first dried in open kilns, excavated in tufaceous sandstone. The last new ones, 37ft. deep by 20ft. in diameter at the top, and tapering down to the bottom, where it is finished off with a brick arch, having a door and iron chute for discharging the dried ore into trucks. These kilns are first charged with wood and ore in layers, each layer of wood being about 5ft. apart. After the kiln is fully charged the wood is lighted, and after being all burnt up, about one-half of the charge is withdrawn—50 tons—and another 50 tons of raw ore, together with wood, added on to the top; after which about 50 tons is withdrawn every third day. This method of drying the ore is found to be very economical as regards fuel, as there is not a large surface of cold material to heat up as is the case with the smaller kilns, which are emptied at each charge. The cost of firewood used in large kilns is about 1s. 6d. per ton of ore dried.

After the ore is taken from the kiln it is then put through the rock-breaker, from which it falls into a hopper, and thence, by automatic feeders, it is fed into the stamp-mortars, when it is pulverised until it passes through a 30-mesh and sometimes a 60-mesh screen. The company intend in the future to use a 40-mesh standard. As the pulverised dust pass through the screens it falls into a narrow trough, when it is conveyed by means of an Archimedian screw into a dust-bin at one end of the battery, and from this bin the pulverised material is lifted with a bucket-belt elevator and discharged on to an 8in. rubber belt with rope edges, and conveyed to and across the hopper 110ft. long, running the entire length of the cyanide plant-house. This hopper has twenty doors for discharging the sand into trucks, which are then run straight out over the percolating vats on to travellers running on rails, which are fitted with hand traversing gearing, enabling a truck to be tipped at any part of the vat. This is an important point, as sand has a tendency to pack if moved about or touched in any way after being tipped into the vat. As a further preventive against packing there is a small traveller running under the main traveller, with a platform just at the height that the sand is to be filled up to. All trucks are tipped over this platform, which breaks the fall and throws the sand off in a light shower all around.

When the vats are filled up to a depth of about 2ft., a strong solution of cyanide—0·4 per cent. is introduced into the bottom of the vat under the filter-cloth, and forced up through the sand until it stands about 2in. above it; the solution remaining under the filter-cloth is then drawn off, and the filtration commences; the 2in. on the surface taking about twenty-four hours to percolate through. After the whole of the strong solution has been taken out of the ore, a weak stock solution is run on the top of the ore to a depth of about 6½in. The cock connecting with the vacuum cylinder is then opened, and in about thirty hours the second solution has passed through; after which about 10in. of water is run on to the top, and when this has gone through the ore the operation is completed. The sludge-door in the vat is opened, and the sand sluiced out by means of two 2in. hose-pipes under a head of 150ft.

The vats are all circular, 22ft. 6in. in diameter and 4ft. in depth, of which 5in. is taken up by the filter bottom, which consists of a wooden grating with edges rounded off on the upper side, having a

strong hessian cloth laid over the top, which acts as a filter. The vats are made of kauri timber, 3in. in thickness, the bottom is held together by six bolts of ¾in. diameter. The staves are about 3in. in width, jointed close, having the bottom rebated into the sides. Each vat is held together by five round-iron hoops, three of which are ⅞in. and two 1in. in diameter, having three turned buckles on each hoop. They are erecting thirteen of these vats, and two sumps of the same diameter, but 6ft. in depth. Each vat holds 30 tons of ore for treatment; and it takes about four days to fill a vat, treat the ore, and have it ready for filling again.

The precipitation boxes are 16ft. long, 2ft. deep, and 17in. wide, divided into twelve divisions, of which the first and last are sand-filters, to clean the solution going in, and to prevent any gold slimes from being washed out.

The manager states that it is too early yet to give the exact cost per ton treated, as they are reducing the cost every month. At the present time it amounts to about 13s. per ton. This includes drying, milling, treatment by cyanide, and all expenses, except the royalty paid the Cassel Company, from the time it leaves the mine-hopper until the bullion is in bars.

The Waihi Company has an Otis ore-crusher at work. The patentees claimed superior advantages for this crusher over any other in use, and that it would pulverise 17cwt. of quartz per hour, with a maximum of 8-horse power to work it. The experience of the Waihi Company is that it pulverises about 4cwt. of quartz per hour, and requires a great deal of attention; while the wear-and-tear is much greater than in a stamp-battery. After seeing this machine at work, and having a knowledge of its crushing capacity, it is one not to be recommended as an econom quartz-crushing mill.

During the year ended the 31st March last, 19,343 tons of ore have beer , which yielded 31,018oz. bullion by amalgamation, and 3,643oz. 5dwt. by the cyanide pro ıe Cassel Company, who purchased the tailings from the Waihi Company that it had st previous to November last for £5,000, have treated 1,425 tons, which yielded by the cyanid ss 1,126oz. bullion.

The total returns from all the claims at Waihi last year was 35,858oz. n, which was obtained from 19,458 tons of ore and 1,625 tons of tailings; while 208 mer employed on wages.

The following is a description of the Cassel Gold Extracting Company's Tailings Cyanide Works, Waihi:—

These works were completed about the end of February, 1894. They are situated in a hollow below the tailings dams, so as to allow the tailings to be run at a good grade into the percolators, and from there to be discharged by sluicing without the necessity for any lifting or re-handling. The building has a frontage of 116½ feet, and is 77 feet in breadth, and includes laboratories and offices situated in a lean-to at one end, and communicating with the main building. The laboratories are fitted up in such a manner that not only may the regular assays and tests in connection with the establishment be carried on there, but also all the experimental and research work of the New Zealand branch of the company. The bullion-room is separate entirely from the assaying department, and the manager has suitable offices on the premises; whilst there is also provision for sleeping accommodation for a portion of the staff.

The plant consists of eight circular percolators, 20ft. in diameter and 4ft. in depth (internal measurements), arranged in two rows, and having an intermediate discharge launder, towards which the vats have a slope of 2in. to facilitute the flow of solutions, and the sluicing out of residues. All the vats are built of specially selected and well seasoned heart-of-kauri, the timbers being 3in. thick. The sides are hooped with 1⅞in. iron bolts, connected and firmly screwed up by nuts and cast-iron boxes, there being three boxes to each ring. The bottom planks are bolted and dowelled tightly together independently of the sides. The filters at the bottom consist of a foundation of 2in. by 2in. slats, 9in. apart, covered by 1in. moulding, which supports the canvas strainer. This filter is very easily laid, and is most effective in practice. Each vat is provided with a cast-iron door, 18in. x 12in., fixed at the bottom of the side near the discharge launder, for the sluicing of residues.

There are two sumps of same size and design as percolators, and situated between percolators and front of the building, and on a sufficiently low elevation. The sumps are floored over. In the same line are placed the reservoir and cylindrical vacuum-chamber, 13ft. x 3ft. 9in., under which latter is provided a small rectangular tank, 12ft. by 8ft., by 18in. deep, capable of holding contents of vacuum chamber. The reservoir is 13ft. 9in. diameter by 5ft. deep (inside measurements), and is at such an elevation as to permit solutions to flow therefrom into percolators. There are three extractor boxes, 12ft. 8in. by 19in., with side discharge for slimes, and a settler for cleaning up.

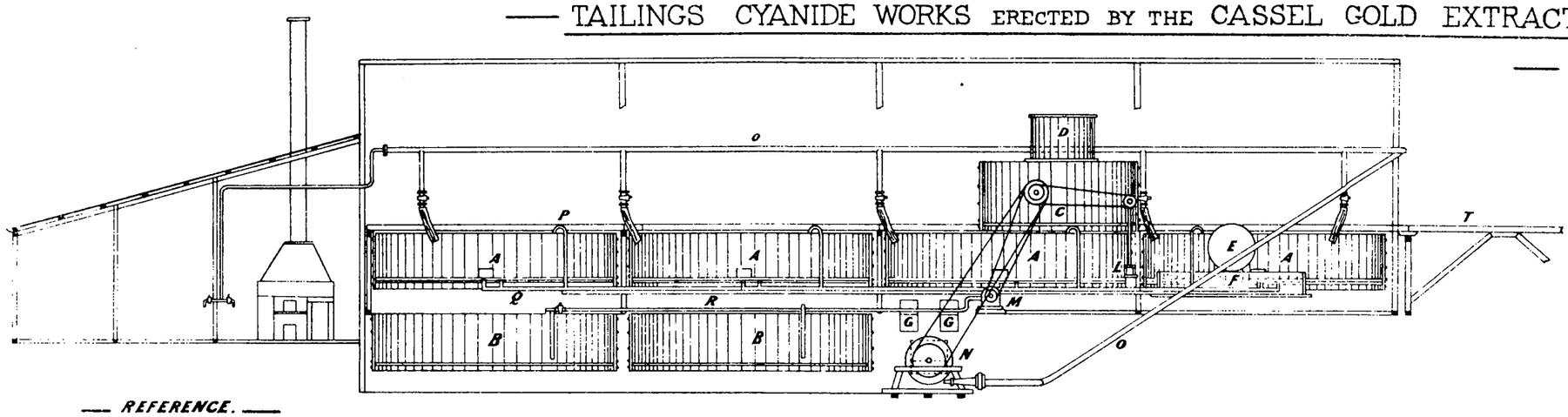
The dissolver is an iron pan, about 3ft. 6in. diameter by 2ft. 6in. high, and is capable of dissolving four boxes, *i.e.*, 1,000lbs. of cyanide, per day. It is so arranged that the requisite amount of strong solution may be run into the reservoir by simply turning a handle.

There is a 4in. centrifugal pump for returning the solutions from the sump to the reservoir, and also an 8in. vacuum pump, which is capable of producing a vacuum of 26in. of mercury. The motive-power is supplied by a 4ft. Pelton, worked under a 60ft. head of water from the company's own race. The machinery runs very smoothly, and the water-supply is more than sufficient to enable the company to run both centrifugal and vacuum pump, and to sluice out their residues at one and the same time.

There is a line of piping running along above each row of percolators, with a connection at each tank for the hose and nozzle, and it is found that one man can empty a vat containing over 40 tons in two hours.

A tramway of about 300 yards connects the upper and lower tailings-pits with the works, and two sets of lines run over the top of each vat, so that the tailings may be equally distributed without the necessity for handling.

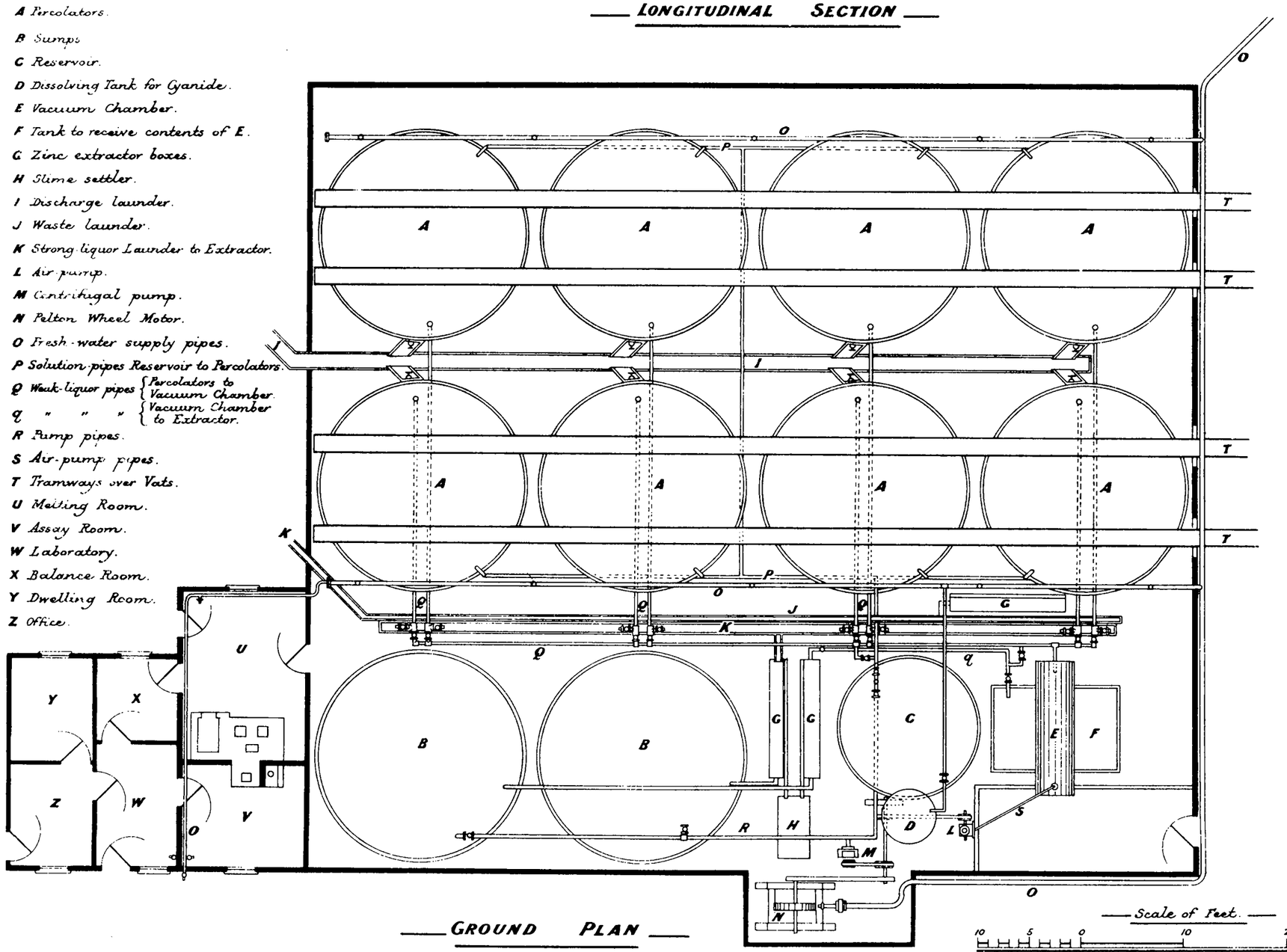
TAILINGS CYANIDE WORKS ERECTED BY THE CASSEL GOLD EXTRACTING Co LTD AT WAIHI NZ.



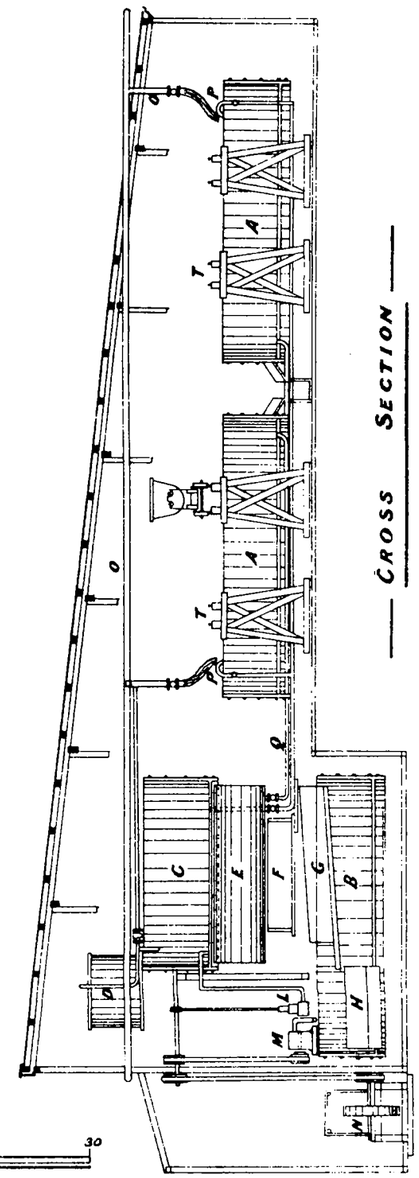
LONGITUDINAL SECTION

REFERENCE.

A Percolators.
B Sumps
C Reservoir.
D Dissolving Tank for Cyanide.
E Vacuum Chamber.
F Tank to receive contents of E.
G Zinc extractor boxes.
H Slime settler.
I Discharge launder.
J Waste launder.
K Strong liquor Launder to Extractor.
L Air-pump.
M Centrifugal pump.
N Pelton Wheel Motor.
O Fresh-water supply pipes.
P Solution-pipes Reservoir to Percolators.
Q Weak-liquor pipes { Percolators to Vacuum Chamber.
q " " " { Vacuum Chamber to Extractor.
R Pump pipes.
S Air-pump pipes.
T Tramways over Vats.
U Melting Room.
V Assay Room.
W Laboratory.
X Balance Room.
Y Dwelling Room.
Z Office.



GROUND PLAN



CROSS SECTION

Scale of Feet.

10 5 0 10 20 30

The chief characteristic of the plant is its extreme simplicity, and the ease of access to any portion of it, whilst the absence of any subdivisions or partitions within the main building allow of the whole of the plant being constantly under the eye of the operator. The system employed of running the solutions into parallel launders instead of pipes enables the solution from each vat to be separately and readily sampled, and any mishap may be at once detected. The usual method of procedure is as follows: Side-tipping trucks are run from the tailings-pit over the top of the vat to be charged. The contents of the trucks are tipped on to cross-bearers resting on struts, which serve to break the fall of the tailings, and to divide them equally over the bottom of the vat. Both tramway and bearers are supported entirely independently of the vats, so that no vibration may be communicated to the latter. A charge consists of sixty-five truck-loads—about 33 tons, dry weight—and, as soon as the vat is full, "strong" solution, about 6 tons of 0·7 per cent., is run on to the top from the elevated reservoir. Provision is made for either upward or downward percolation, but the latter is usually adopted. The solution is now permitted to gravitate through the mass of the charge, and to eventually percolate through the false bottoms into the series of launders, in which it is conducted to No. 1, No. 2, or No. 3 extractor, according to its strength in bullion and cyanide. About twenty-four hours after the "strong" solution, about an equal amount of "weak" solution (0·25 per cent.) from the sumps is pumped on and allowed to gravitate. The residues are now washed with about 10 tons of water, in two charges, which are rapidly drawn off by suction, and which displace the "weak" solution and leave the residues free of either dissolved bullion or cyanide. The solutions run from the extractor-boxes to the sumps, whence they are pumped to the reservoir or percolators, to be used over again for sluicing or weak solutions as required. The slimes from the zinc are cleaned up and melted fortnightly.

STATEMENT showing the RESULTS of Mining Operations in the OHINEMURI-HAURAKI DISTRICT for the Year ended 31st March, 1894.

Locality and Name of Mine.	Area.	Average Number of Men employed.		For Owners.			For Tributers.		Tailings.	
		Wages-men or Owners.	Tributers.	Quartz crushed.	Bullion obtained. Amalgamation.	Bullion obtained. Cyanide.	Quartz crushed.	Bullion obtained. Amalgamation.	Quantity treated.	Bullion obtained. Cyanide.
Ohinemuri County.	A. R. P.			Tons.	Oz. dwt.	Oz. dwt.	Tons.	Oz. dwt.	Tons.	Oz. dwt.
Maratoto—Maratoto	18 0 0	3	..	200	2,349 5	..	..	..	..	..
	18 0 0	3	..	200	2,349 5	..	..	..	..	..
Karangahake—										
Woodstock	72 1 18	16	2	568	1,517 0	..	59	71 0	..	..
Crown	108 0 0	112	..	4,544	..	11,130 15	..	..	..	..
Earl of Glasgow	27 0 26	3	1	20	35 0	..	..	..	..	..
Diamond	9 3 12	2	..	9	38 0	..	..	..	..	..
Sundries	..	10	..	..	..	..	..	..	..	..
	217 1 16	143	3	5,141	1,590 0	11,130 15	59	71 0	..	..
Owharoa—										
Smile of Fortune	12 3 2	6	3	1,023	112 0	..	230	85 10	..	..
Cadman	29 2 20	2	..	33	38 0	..	..	..	..	..
	42 1 22	8	3	1,056	150 0	..	230	85 10	..	..
Waitekauri—Sundries	..	28	8	120	130 0	..	..	..	..	..
Waitekauri North—Golden Cross ..	26 0 20	20	..	600	1,632 0	..	..	..	..	..
Komata—Komata Company ..	67 0 16	30	..	1,708	8,996 0	..	..	..	1,075	5,610 0
	93 0 36	78	8	2,428	10,758 0	..	..	..	1,075	5,610 0
Waihi—										
Waihi Company	327 0 0	195	..	19,343	31,018 0	3,643 5	..	..	..	..
Silverton	83 0 38	4	..	115	..	..	..	..	200	321 8
Sundries	..	9	..	..	750 0	..	..	..	1,425	*1,126 0
	410 0 38	208	..	19,458	31,768 0	3,643 5	..	..	1,625	1,447 8
Totals	781 0 32	440	14	28,283	46,615 5	14,774 0	289	156 10	2,700	7,057 8

* Bullion from Waihi Company's tailings treated by Cassel Company.

NOTE.—The areas shown do not include the whole of the land occupied, but only that from which the returns are derived.

Te Aroha.

There are still a few men working on this field, but only partial success has as yet attended their labours. Sometimes a patch of good ore is found, but in many cases it cuts out very quickly, so that while a claim may pay very well for working for a few months, it takes some time again before another patch of payable ore is struck. It may be said that the shot of auriferous stone got in the New Find Mine has been the only one of any great extent, and the one where the great bulk of the gold from this field was obtained. Mr. H. Adams is now the sole proprietor of this mine, and of the only crushing-plant on the field. The success attending his operations since the property was purchased from the Te Aroha Gold and Silver Company has not been very great. He is carrying on from year to year with the hope that another rich patch of auriferous ore will be struck, which will repay him yet for all his labour.

In December last, Mr. Adams opened out on the No. 2 reef of the New Find, and got on to a run of auriferous stone which appeared to be payable for working. Streaks and blotches of gold could be seen in the stone all through the lode, which was about 8ft. wide, and at the time of my visit he had driven about 30ft. on the lode; but at the place he opened out he had only about 30ft. of backs between the floor and the surface. Mr. Adams feels confident of finding another shot of gold-bearing stone if he had the means to prospect the ground. He contemplated constructing an adit from what is known as the Galena holding, where one is now in for about 100ft. If this adit were extended for about 1,100ft. it would cut through the country, when the following lodes should be found if they live down to the depth—namely, the Waiorongomai, Three-foot, Galena, New Find, Diamond Gully, and a new reef found under the hopper of the late Eureka Company. The proposed adit would be 400ft. below the lowest level in the New Find Mine, and about 800ft. below the cap of the reef.

Te Aroha is a field that may linger on for years without anything great being discovered, especially when no prospecting work of any consequence is going on; but my firm belief is that if this field were properly prospected it would give remunerative employment to a large population. There is a great deal of complex ore on this field, which contains both gold and silver; but it also contains copper, galena, and zinc-blende, and this makes it difficult of treatment so as to yield a fair percentage of the gold and silver. Some ore of this description was sent to Maryborough, in Queensland, for treatment, which gave good results; but it was found that, after deducting all expenses in connection with the transit and smelting, it would not leave sufficient to work the lodes at a profit.

Since my former visit, the 20-head crushing-battery of American stamps has been erected inside the building, in lieu of the original 20-heads of stamps that was formerly purchased by Messrs. Firth and Clarke from the Piako Company at the Thames, which was removed. As soon as the alterations in the crushing-plant were made, dry-crushing was adopted, and the pulverised material treated by the Cassel process; but it was found, after working for about two months, that there was too large a percentage of copper in the ore for it to be economically treated with cyanide solutions. The Cassel process was then abandoned, and wet-crushing again resorted to, the gold being saved in the ordinary way. When the tailings are found to have gold in them to the value of £1 per ton, they are treated in the vats with a cyanide solution.

On inquiry of Mr. Adams, as to the expense of crushing dry as against wet-crushing, he thinks the wear-and-tear is four times as much in wet-crushing as it is in dry; but about one-third more stone can be put through by the wet process. He reckons that the actual wear and tear in connection with the stamps is about 1s. for every truck of stone—1⅓ tons—crushed, and 6d. for gratings. He used a rock-breaker with a 10in. face, which reduces about 40 tons in 8 hours to a maximum of 1½in. in diameter. The ore thence goes into hoppers, and is fed by Challenge ore-feeders into the stamp mortar. Mr. Adams thinks the use of the ore-feeders alone increases the crushing capacity of his battery nearly 20 per cent.

During the year ended the 31st March last, 1,329 tons of ore was crushed, and 592 tons of tailings treated. The latter was by the cyanide process, which yielded 2,032oz. 3dwt. gold.

There are two other parties who have claims on this field—namely, Newsham and party and Garvin and Newsham. The former party have a claim on the ground formerly held by the New Era Company. Prior to my visit to the district they had 166 tons of stone crushed, which yielded 65½oz. gold. The quartz is taken from the mine by the County tramway, and is crushed at the mill; the expense of crushing being 6s. per ton.

Garvin and Newsham, during the last year, went out prospecting on account of a prospecting association, and found payable stone in ground known as the Inverness holding. An entirely new reef was discovered, about 2ft. wide, and the first crushing of 12 truck-loads gave a yield of 57oz. gold, worth £3 4s. 9d. per oz. They picked the stone to send to the battery, but intended trying the rest of the stone to ascertain the value of the quartz in the lode if the whole of it is sent to the crushing-battery. There is a good quartz hopper on the ground, and a level, which was constructed some years ago by the Inverness Company, which they are using to work the ground.

The total quantity of ore crushed on this field during the last year amounted to 1,928 tons, which yielded 2,504oz. gold; and 29 men were employed in carrying on the operations in connection with the mines.

STATEMENT showing the RESULTS of Mining Operations in the TE AROHA DISTRICT for the Year ended 31st March, 1894.

Locality and Name of Mine.	Area.	Average Number of Men employed.		For Owners.			For Tributers.		Tailings.	
		Wages-men or Owners.	Tributers.	Quartz crushed.	Gold obtained. Amalgamation.	Gold obtained. Cyanide.	Quartz crushed.	Gold obtained. Amalgamation.	Quantity treated.	Gold obtained. Cyanide.
Piako County.										
Waiorongomai and Te Aroha—	A. R. P.			Tons.	Oz. dwt.	Oz. dwt.	Tons.	Oz. dwt.	Tons.	Oz. dwt.
New Find	31 0 36	14	5	1,284	..	..	45	31 1	592	2,001 2
Newsham's	5 0 0	3	..	294	107 10	..	..	..	..	..
Loyalty	10 0 0	4	..	55	93 0	..	..	..	..	..
Sundries	..	3	..	250	282 7	..	..	..	..	..
Totals	46 0 36	24	5	1,883	482 17	..	45	31 1	592	2,001 2

NOTE.—The areas shown do not include the whole of the land occupied, but only that from which the returns are derived.

It will be seen that, taking the whole of the mining operations in the North Island, the value of the gold and bullion obtained was £30,256 16s. 1d. more than for the previous year. The following comparative statement will show the districts in which this increase has taken place.

COMPARATIVE STATEMENT of RETURN for HAURAKI DISTRICT for the Years ended 31st March, 1894 and 1893 respectively.

Name of County.	Area.	Average Number of Men employed.		For Owners.					For Tributers.		Tailings treated.			Estimated Value of Gold and Bullion.
		Contractors, Wages-men, and Owners.	Tributers.	Quartz.	Mullock.	Gold obtained. Amalgamation.	Bullion obtained. Amalgamation.	Bullion obtained. Cyanide.	Quartz.	Gold obtained. Amalgamation.	Quantity.	Gold obtained. Amalgamation.	Gold obtained. Cyanide.	
1894.														
Coromandel	A. R. P. 532 3 5	157	42	Tons cwt. lb. 9,861 10 29	Tons. ..	Oz. dwt. gr. 5,347 7 12	Oz. dwt. ..	Oz. ..	Tons cwt. lb. 380 5 4	Oz. dwt. 1,197 10	Tons. 2,388	Oz. dwt. 54 4	Oz. dwt. 3,420 4	£ s. d. 17,500 0 0
Thames	1,287 0 21	407	253	18,694 19 23	14,970	23,684 7 0	..	..	15,559 10 87	8,541 8	13,220	2,411 4	..	92,650 0 0
Ohinemuri	781 0 32	440	14	28,283 0 0	..	..	46,615 5	14,774	289 0 0	156 10	2,700	..	7,057 8	107,000 15 0
Piako	46 0 36	24	5	1,833 0 0	..	482 17 0	..	..	45 0 0	31 1	592	..	2,001 2	2,500 0 0
Total	2,647 1 14	1,028	314	58,672 9 52	14,970	29,514 11 12	46,615 5	14,774	16,273 15 91	9,926 9	18,900	2,465 8	12,478 14	219,650 15 0
1893.														
Coromandel	523 0 38	212	42	12,022 1 21	..	10,553 1 0	..	..	381 6 15	1,377 15	2,760	11 13	1,011 11	189,393 18 11
Thames	1,013 1 10	423	253	25,106 11 25	21,106	19,325 10 0	..	3,985	13,025 0 0	7,531 12	19,309	4,478 12	..	
Ohinemuri	991 1 17	449	7	22,526 0 0	..	1,545 0 0	36,937 10	3,266	245 0 0	177 0	..	..	..	
Piako	36 0 36	19	4	1,333 0 0	..	820 0 0	..	..	186 0 0	60 0	1,650	297 14	..	
Total	2,564 0 21	1,103	306	60,987 12 46	21,106	32,243 11 0	36,937 10	7,251	13,837 6 15	9,146 7	23,719	4,787 19	1,011 11	189,393 18 11

	£ s. d.
Estimated value, 1894	219,650 15 0
" 1893	189,393 18 11
Increase for 1894	£30,256 16 1

STATEMENT showing the whole of the QUARTZ-CRUSHING MACHINES and APPLIANCES for treating Auriferous and Argentiferous Ores in the HAURAKI MINING DISTRICT for the Year 1893–94.

Locality where Machine is situated.	Name of Machine.	Number of Rock-breakers.	Number of Stamps.	Number of Ore-crushers and Lamberton Mills.	Number of Berdans.	Number of Pans.	Number of Settlers.	Number of Mortars.	Number of Retorts.	Number of Furnaces for Gold-melting.	Number of Furnaces for Assay Purposes.	Number of Plants for Cyanide Process.	Concentrating Plant.	Driven by Steam-power.	Driven by Water-power or Hand-power. W.	H.
Coromandel County—																
Coromandel ..	Kapanga	..	10	..	2	..	..	1	1	..	..	..	..	1	..	
" ..	Coromandel Beach	..	15	..	1	..	..	1	1	..	..	..	..	1	..	
" ..	Mayn's	..	9	..	8	..	..	1	2	..	..	..	..	..	1	0
Opitonui ..	Gale's	1	10	..	2	..	..	1	2	..	..	..	..	..	1	0
Owera	Owera	1	10	..	2	..	..	1	2	..	..	..	..	..	1	0
Cabbage Bay ..	Cabbage Bay ..	..	2	..	2	..	..	1	1	..	..	..	..	..	1	0
Matarangi ..	Ocean View ..	..	15	..	2	2	..	1	2	..	..	..	..	1	..	
Kuaotunu ..	Try Fluke ..	..	11	..	3	1	..	1	2	..	..	1	..	1	..	
" ..	Great Mercury ..	..	10	..	1	4	2	4	1	..	..	1	..	1	..	
" ..	Red Mercury ..	..	10	..	1	4	2	1	2	..	..	..	..	1	..	
" ..	Irene	..	10	..	5	4	..	2	2	..	..	..	..	1	..	
" ..	Mariposa ..	..	10	..	1	2	2	1	1	..	..	..	..	1	..	
		2	122	..	30	17	6	16	19	..	..	2	..	8	4	0
Thames County—																
Tapu	Pepper's	..	15	..	3	..	..	3	3	1	..	..	..	..	1	0
" ..	A. McMahon ..	..	..	..	..	..	..	1	..	..	..	..	..	..	0	1
Waiomo ..	Monowai	1	..	..	1	4	2	1	1	..	..	..	..	..	1	0
Puru	Ballance	..	4	..	1	..	..	1	1	..	..	..	..	..	1	0
Tararu	Dixon's	..	28	..	7	2	..	1	1	..	..	..	..	..	1	0
"	Berry's	..	1	..	3	..	..	1	2	..	..	..	..	..	1	0
"	Norfolk	..	40	..	6	..	..	..	2	..	..	..	1	..	1	0
Karaka	Claremont ..	..	1	..	1	..	..	1	1	..	..	..	..	..	1	0
"	Taylor's	..	6	..	3	..	..	1	1	..	..	..	..	..	1	0
"	Karaka	..	5	..	1	1	..	1	3	..	..	..	..	..	1	0
Otunui	Eureka	..	12	..	4	..	..	1	1	..	..	..	..	1	..	
Puriri	Puriri	..	6	..	2	..	..	1	1	..	..	..	..	..	1	0
Tairua	Bonnie Scotland ..	..	20	..	6	..	..	2	1	..	..	..	..	1	..	
Thames (Hill St.)	W. S. McCormick ..	..	..	..	1	..	..	1	1	..	..	..	..	..	0	1
" (Richmond Street)	Thomas Boyle ..	..	..	..	..	..	..	1	..	..	..	..	..	..	0	1
" Parawai	James McLaren ..	..	..	..	..	..	..	..	1	..	..	..	..	..	0	1
		1	138	..	39	7	2	18	19	1	..	..	1	2	10	4
Thames Borough ..	Brown's	..	..	..	4	8	4	..	2	..	..	..	2	..	1	0
" ..	Bank's	..	..	..	1	3	..	1	2	..	..	..	..	..	1	0
" ..	Kuranui	..	20	..	10	..	..	2	1	..	..	..	..	..	1	0
" ..	Moanataiari ..	..	41	..	21	4	..	2	6	3	..	..	..	..	1	0
" ..	Stanley	..	..	..	3	6	..	..	..	..	..	..	..	..	1	0
" ..	Comer's	..	20	..	5	..	..	1	2	..	..	..	..	..	1	0
" ..	Bawden's.. ..	..	..	..	2	13	..	1	1	1	..	..	..	..	1	0
" ..	Saxon	..	33	..	8	3	..	2	2	1	1	..	..	..	1	0
" ..	Cambria	..	21	..	13	1	..	1	2	..	..	..	..	..	1	0
" ..	Waiotahi ..	..	21	..	5	..	..	2	2	1	..	..	..	1	..	
" ..	Fame and Fortune	..	21	..	16	..	..	1	2	..	..	..	..	..	1	0
" ..	School of Mines ..	..	2	..	1	1	1	3	3	1	4	1	..	..	1	0
" ..	Bank of New South Wales	..	..	..	..	..	..	2	..	2	1	..	..	..	0	1
" ..	H. P. Stark ..	..	..	..	..	..	..	..	..	..	1	..	..	..	0	1
" ..	E. H. Whitaker ..	..	..	..	..	..	..	..	..	..	1	..	..	..	0	1
" ..	Bank of New Zealand	..	..	..	..	..	..	2	..	3	..	..	..	..	0	1
" ..	Pahau Street ..	..	..	..	4	2	..	1	1	..	..	..	..	..	1	0
" ..	Bulls's	..	23	..	14	..	..	2	7	1	1	..	..	..	1	0
" ..	Fairmile	..	..	..	1	..	..	1	..	..	1	..	..	..	0	1
" ..	George Peel ..	..	..	..	..	..	..	1	..	1	1	..	..	..	0	1
" ..	James Finlay ..	..	..	..	..	..	..	..	..	1	1	..	..	..	0	1
" ..	D. Henderson ..	..	..	..	..	..	..	1	..	..	..	..	..	..	0	1
" ..	L. Mellrose ..	..	..	..	..	..	..	1	..	..	..	..	..	..	0	1
" ..	C. Palmer ..	..	..	..	..	..	..	1	..	..	..	..	..	..	0	1
		..	202	..	108	41	5	28	33	15	12	1	2	1	13	10
Ohinemuri County—																
Maratoto ..	Maratoto	..	..	..	..	2	1	2	2	1	..	..	..	..	1	0
Paeroa	C. Rhodes ..	1	..	..	..	..	..	2	1	3	1	..	..	..	0	1
Karangahake ..	Crown	2	21	..	1	..	..	6	..	1	1	1	..	..	1	0
" ..	Ivanhoe	1	4	..	..	2	1	2	2	1	..	..	..	..	1	0
Owharoa ..	Smile of Fortune ..	..	15	..	2	..	..	1	2	1	..	..	..	..	1	0
Waitekauri ..	Komata	1	30	..	..	6	3	2	3	..	..	1	..	..	1	0
" ..	Golden Cross ..	..	10	..	2	..	..	1	1	..	..	1	..	..	1	0
" ..	Jubilee	..	10	..	5	2	1	1	2	..	..	..	..	1	..	
" ..	Mangakara ..	..	9	..	3	..	..	1	2	..	..	..	..	..	1	0
" ..	Hollis	..	..	..	1	..	..	1	1	..	..	..	..	..	0	1
Waihi	Waihi	2	60	..	..	16	8	..	3	1	1	1	..	..	1	0
"	Cassel	..	..	..	..	..	..	..	..	..	..	1	..	..	1	0
"	Silverton	..	15	..	1	2	1	1	3	..	..	1	..	..	1	0
		7	174	..	15	30	15	20	22	8	3	6	..	1	10	2

STATEMENT showing the whole of the QUARTZ-CRUSHING MACHINES and APPLIANCES for treating Auriferous and Argentiferous Ores in the HAURAKI MINING DISTRICT for the Year 1893-94 —*continued.*

Locality where Machine is situated.	Name of Machine.	Number of Rock-breakers.	Number of Stamps.	Number of Ore-crushers and Lamberton Mills.	Number of Berdans.	Number of Pans.	Number of Settlers.	Number of Mortars.	Number of Retorts.	Number of Furnaces for Gold-melting.	Number of Furnaces for Assay purposes.	Number of Plants for Cyanide Process.	Concentrating Plant.	Driven by Steam-power.	Driven by Water-power or Hand-power.
Piako County—															
Waiorongomai ..	Te Aroha	1	20	..	1	..	..	2	4	1	1	1	..	..	1 0
City of Auckland ..	Young's	..	2	..	..	2	2	1	2	1	..	..	..	1	..
" ..	Bank of New Zealand	1	..	..	..	1	1	2	6	7	2	..	..	..	0 1
" ..	Stanley Street ..	..	..	1	1	2	2	2	2	1	1	..	..	1	..
" ..	H. M. Shepherd ..	..	..	..	..	..	..	1	..	1	..	..	..	..	0 1
		1	2	1	1	5	5	6	10	10	3	..	..	2	0 2
Totals.															
Coromandel County		2	122	..	30	17	6	16	19	..	..	2	..	8	4 0
Thames County		1	138	..	39	7	2	18	19	1	..	..	1	2	10 4
Thames Borough		..	202	..	108	41	5	28	33	15	12	1	2	1	13 10
Ohinemuri County		7	174	..	15	30	15	20	22	8	3	6	..	1	10 2
Piako County		1	20	..	1	..	..	2	4	1	1	1	..	..	1 0
City of Auckland		1	2	1	1	5	5	6	10	10	3	..	..	2	0 2
Totals		12	658	1	294	100	33	90	107	35	19	10	3	14	38 18

The following table shows the number of tons of stone and mullock crushed, and the yield of gold, from the northern goldfields since the returns have been supplied to the Mines Department. The Thames returns include the Ohinemuri District up to 1886-87:—

RETURN of STONE, &c., CRUSHED—THAMES DISTRICT.

District.	Number of Tons of Quartz and Mullock crushed or sold.	Yield of Gold.	Average Yield of Gold per Ton.
		Oz.	Oz. dwt. gr.
Coromandel—			
1st April, 1880, to 31st March, 1881 ...	720	4,960	6 18 0
" 1881, " 1882 ...	3,358	7,352	2 4 0
" 1882, " 1883 ...	2,907	7,577	2 12 0
" 1883, " 1884 ...	1,043	4,018	3 17 0
" 1884, " 1885 ...	456	3,201	7 0 0
" 1885, " 1886 ...	550	3,382	6 3 0
" 1886, " 1887 ...	305	4,170	13 13 0
" 1887, " 1888 ...	1,923	6,774	3 10 5
" 1888, " 1889 ...	2,149	8,090	3 15 7
" 1889, " 1890 ...	1,690	6,708	3 19 9
" 1890, " 1891 ...	5,650	9,838	1 14 19
" 1891, " 1892 ...	13,029	12,191	0 18 17
" 1892, " 1893 ...	15,163	12,954	0 17 2
" 1893, " 1894 ...	12,629	9,969	0 15 18
Totals	61,572	101,184	1 12 2
Thames—			
1st April, 1878, to 31st March, 1879 ...	41,917	57,207	1 7 7
" 1879, " 1880 ...	33,017	59,576	1 16 2
" 1880, " 1881 ...	32,405	53,154	1 12 19
" 1881, " 1882 ...	30,698	45,803	1 9 20
" 1882, " 1883 ...	25,867	43,311	1 13 12
" 1883, " 1884 ...	34,228	54,878	1 12 2
" 1884, " 1885 ...	31,496	37,705	1 4 4
" 1885, " 1886 ...	35,998	61,540	1 14 4
" 1886, " 1887 ...	34,827	38,142	1 1 22
" 1887, " 1888 ...	32,819	35,949	1 1 11
" 1888, " 1889 ...	47,363	35,796	0 15 3
" 1889, " 1890 ...	60,753	33,817	0 11 14
" 1890, " 1891* ...	61,756	38,113	0 12 8
" 1891, " 1892 ...	86,150	45,735	0 10 15
" 1892, " 1893 ...	78,547	31,336	0 7 23
" 1893, " 1894 ...	62,444	34,637	0 11 2
Totals	730,285	706,699	0 19 9

* This includes 50,856 tons of mullock crushed the last two years.

RETURN of STONE, &c., CRUSHED—THAMES DISTRICT—*continued.*

District.	Number of Tons of Quartz and Mullock crushed or sold.	Yield of Gold.	Average Yield of Gold per Ton.
		Oz.	Oz. dwt. gr.
Ohinemuri—			
1st April, 1887, to 31st March, 1888 ...	2,388	3,406	1 8 13
" 1888, " 1889 ...	3,795	3,679	0 19 9
" 1889, " 1890 ...	4,773	8,564	1 15 21
" 1890, " 1891 ...	9,902	*12,914	1 6 2
" 1891, " 1892 ...	13,865	†23,659	1 14 2
" 1892, " 1893 ...	22,771	‡43,405	1 18 3
" 1893, " 1894 ...	31,281	35,666	1 2 18
Totals	88,775	131,293	1 9 13
Te Aroha—			
1st April, 1883, to 31st March, 1884 ...	4,262	4,629	1 1 17
" 1884, " 1885 ...	11,042	9,506	0 17 5
" 1885, " 1886 ...	6,552	4,489	0 13 17
" 1886, " 1887 ...	4,743	3,658	0 15 10
" 1887, " 1888 ...	7,166	2,918	0 8 3
" 1888, " 1889 ...	1,381	1,113	0 16 3
" 1889, " 1890 ...	4,894	§20,416	4 3 10
" 1890, " 1891 ...	280	557	1 19 18
" 1891, " 1892 ...	2,722	979	0 7 5
" 1892, " 1893 ...	3,169	1,178	0 7 2
" 1893, " 1894 ...	2,270	833	0 7 8
Totals	48,481	50,276	1 0 17
Grand totals from North Island ...	929,113	989,452	1 1 7

* The gold obtained includes 42,331oz. bullion. † Includes bullion, 22,737oz. ‡ Includes bullion, 41,683oz. § Is bullion worth only 11s. 6d. per ounce?

NOTE.—Bullion from Ohinemuri equal to 68,446oz. 13dwt., valued at £107,000: this is reduced in the table to the value of gold.

Bullion from Te Aroha equal to 2,515oz.; value, £2,500: this is reduced in the table to the value of gold.

THE GEOLOGY, RESOURCES, AND FUTURE PROSPECTS OF THE THAMES GOLDFIELD.

A valuable report on the geology, resources, and future prospects of the Thames Goldfield has been forwarded me by Mr. James Park, F.G.S., the director of the Thames School of Mines, who also compiled a map from the surveys of Mr. Bayldon and other surveyors, which shows all the lines of reefs, with the displacements that have from time to time taken place. The report, in conjunction with the map, gives a far better idea of the Thames Goldfield than anything that has ever yet been published. A large amount of time and labour has been expended in preparing this map, and more information can be obtained from it than in a whole book of letterpress. Everything is seen at a glance, and in a few minutes the whole of the line of reefs, with breaks and displacements, are grasped and fixed in one's mind. No one but a person residing for a considerable time on the field could have prepared such a map, the accuracy of which is acknowledged by all the mine-managers. When examining the Thames Goldfield, along with Messrs. Murray and McKay, in the beginning of the present year, this map was of the greatest assistance to us, and, so far as our examinations went, it proved to be correct. The people connected with the Thames Goldfield owe a debt of gratitude to Mr. Park for the time and labour he has given to further the interests of the place, and in bringing together such a fund of information at a glance, to facilitate the development of the mines.

The following is the report referred to, which, in conjunction with the attached map, will be of the greatest interest to those connected with the mining industry:—

Although twenty-seven years have elapsed since the discovery of gold at the Thames, the greater part of the mining operations of this productive goldfield have been confined to an area not much over a square mile in extent. The natural result of this activity extending over so long a period, and in such a limited area, has been to exhaust most of the more accessible and readily-obtainable gold; and it is now evident to every one, that the question of deep-sinking and the development of the back-country must claim the attention and serious consideration of our mining men if the Thames is to maintain for long its position as the leading reefing district in New Zealand.

It is abundantly evident that the time has arrived when the future prosperity of this field must depend upon the successful development of new ground; and, in order to direct the necessary operations with an intelligent understanding, and a due regard of the great issues at stake, we must possess an adequate and accurate knowledge of the structure and arrangement of the gold-bearing country, and the distribution of the reefs.

Four years ago I read a short paper on "The Geology of the Thames Goldfield" before the Australasian Association for the Advancement of Science, at the meeting held at Melbourne in 1890. Since that date I have become thoroughly acquainted with the physical features and mines of this interesting field, and have also collected much additional information relating to its geological structure. I have also received much assistance from Professor Hutton's valuable petrological

paper "On the Rocks of the Hauraki Goldfields," * besides having access to the memoirs and works of Becker, Judd, Zirkel, Von Cotta, and others.

The rocks of this goldfield present many puzzling features to the geologist. They are unlike any others in New Zealand, or, indeed, in the Southern Hemisphere; and their characters can only be accurately determined by means of the microscope, supplemented by careful field observations.

When I first examined this district, in the end of 1889, I came to the conclusion that the gold-bearing rocks were all of pyroclastic origin. At that time my knowledge of the field was principally of that portion lying to the seaward of the Moanataiari Fault. My more extended surveys of recent years have proved the existence of not only breccias and tuffs, but also of solid lavas, thus confirming the conclusions of Professor Hutton.

Geological Structure.

I have shown on the accompanying geological map two lines of section, to illustrate the geological structure, and the distribution and direction of the main system of reefs. One extends from Rocky Point, beyond Tararu, to Totara Point, south of the Kauaeranga River; the other from the Thames foreshore north-eastward to Punga Flat. The horizontal and vertical projection of the sections is on the same scale as that of the map. The geological formations, reefs, and mine-workings are thus shown in their true places with respect to the surface-contours and sea-level. The shafts, cross-cuts, and reefs shown in the cross-section along the foreshore from Kuranui Hill to the Karaka Stream were reduced by me from the working-plans of the mines in that area prepared and surveyed by Mr. H. D. Bayldon, mining engineer. A study of this section will therefore afford accurate information respecting the relative positions and depths of the different shafts, the number of reefs, and the depths to which they have been traced, as well as the extent of the unworked gold-bearing ground. The section to Punga Flat will show the nature and extent of the changes effected by the principal faults; while a study of the map itself will afford an appreciation of the number of reefs and the character of the country to be met with in an extension of the Moanataiari adit-level, as well as the positions and linear extent of all the main lodes on the field.

The section from Rocky Point to the Kauaeranga supplies the key and explanation of the geological structure of the whole goldfield; and, in view of deep-sinking, I shall give a detailed description of the facts and features displayed between these points.

Rocky Point to Kauaeranga River.

The basement rock of the district is exposed as a small patch on the beach, between high- and low-water mark, in the first small indentation to the north of the fishing-rocks at Rocky Point. Here it consists of blue and yellowish-grey slaty shales, but on the coast-road north of Waikawau these are found to be associated with slaty breccias and greywackes. The blue shales are somewhat broken and disturbed, the dip varying from S.S.W. to W.S.W. at flat angles, varying from 26° to 30°. In former years the outcrop was over a chain square in extent, but at the present time it is only a few square yards, having become covered up by recent accumulations of beach-sands and gravels. Another small outcrop of the blue slaty shales is exposed in the bed of Waiohanga Creek, about half a mile distant on the line of strike, and at an elevation of about 400ft. above the sea.

A few chains north of Rocky Point the slaty shales are followed, apparently quite conformably, by a great thickness of pale yellow or grey-coloured siliceous shales or mudstones, which rise into steep rocky cliffs, and form Rocky Point itself, as well as the outlying fishing-rocks and islets. These mudstones are much jointed and broken, and show evidences of having been at one time much disturbed and crushed. They exhibit no distinct lines of bedding or stratification, but in a few places the lines of different coloured materials would indicate a dip to the S.S.W., or the same as that of the underlying blue shales. About 3 chains south of the point—that is, on the side facing Tararu—they are curved, bent, and tilted up at high angles, and terminate very abruptly and steeply against the overlying volcanic breccias. At their base they possess a bluish-grey colour when seen in the solid, but they weather for a great depth to a yellowish-grey colour. They are highly pyritous, and occasionally interlaminated with thin layers of grit, consisting of small rounded particles of hard mudstone, mostly of uniform size. The blue shales also contain similar grit-bands, as well as nests and veins of pyrites.

The age of these old mudstones and slaty shales is still a matter of much doubt. Up to the present time they have yielded no distinct fossils, and the only remains that could be considered of organic origin are some small, dark-blue tube-like markings in the lower blue shales, which may be referred to annelid- or worm-trails. These markings are, however, too obscure to fix the age of these rocks, and, until more satisfactory evidence is obtained, they may be regarded of Lower Secondary or Upper Palæozoic age, most probably the latter.

Passing southward, towards Tararu, at the point where the yellowish mudstones abruptly terminate, they are followed by a hard blue, or bluish-green andesitic tuff or ash-rock, which abuts against and overrides them, resting both on the mudstones and shales. Where it rests on the blue slaty shales it contains small fragments of shale and masses of jasperoid quartz. But on the Tararu side, for the first 30ft. from the mudstones, it is almost free from foreign matter. At the old quarry-face, a few yards beyond this, it becomes quite brecciated with numerous angular fragments of blue shale, varying from $\frac{1}{4}$in. to $\frac{1}{2}$in. in length, but in some layers the fragments are over 3in. in diameter, and so abundant as to form a slaty breccia.

When solid and free from slaty particles this tuff possesses a dark greyish-blue colour, and shows a finely crystalline structure, and might readily be mistaken for a solid lava. It decomposes rapidly when exposed to the influence of rain and other atmospheric agencies. It first assumes a

* "Proceedings of Australasian Association for the Advancement of Science," 1888, p. 245.

greyish-green or purple colour, and soon becomes speckled with small, white, rounded particles, which apparently owe their origin to the decomposition and kaolinizing of its feldspars. It then passes into a fairly even or uniform yellowish-brown rock of moderate hardness, which, in its turn, gradually assumes a pale-grey or yellowish-grey colour, due to the abstraction of its iron-oxides. In the latter state it is a very striking and instructive rock, and, to outward appearance, is similar to the "kindly" gold-bearing rocks to be described hereafter. When it contains slaty particles, these stand out, black and undecomposed, in very marked contrast to the bleached and weathered tuff-matrix. This slaty brecciated tuff, in all its different stages of decomposition, is well exposed in the quarry-face a few chains north of Rocky Point.

On the beach near the mouth of Waiohanga Creek, on the smooth water-worn ledges at high-water mark, the tuffs, now free from slaty inclusions, are intersected by a number of small parallel mineral-veins, many of which are filled with a greenish-grey material resembling the matrix of the enclosing rocks. The strike of these veins is north-east to south-west, and they are generally standing vertical. They vary from a mere thread to 6in. in thickness, are often branching and faulted, and in many ways afford an excellent object-lesson in the structure and behaviour of lodes. A few chains further along the beach the tuffs are again similarly intersected by another system of parallel veins of pyritous quartz, while large veins and segregated masses of calcite are plentiful. The calcite veins often possess a comb-structure, and in the centre, the opposite and corresponding layers terminate in beautiful scalenohedrons. In some of these veins I have found bunches of galena and blende associated with iron- and copper-pyrites. The assays of the galenas proved that they were poor in both gold and silver.

Between this point and Tararu Creek the tuffs pass imperceptibly into coarse breccias, consisting of irregular-shaped masses of greenish-grey andesite or tuff, enclosed in an andesitic matrix. In some places they contain large angular fragments of slaty shale, but these become rare as Tararu Creek is approached. From Rocky Point to Tararu the tuffs and breccias exhibit no distinct lines of stratification, and the southerly dip, which they seem to possess, is only indicated by the direction of the layers of the different materials.

Just before Tararu is reached the coarse breccias are followed by a narrow belt of a greenish-grey compact tuff, or partially-decomposed andesitic lava, containing a number of gold-bearing quartz reefs, which pursue a general north-east course, and traverse the City of Dunedin, Norfolk, and Sylvia mining leases in Tararu Valley. This is the lowest horizon of payable metalliferous veins in the Thames district. The metallic sulphides which accompany the gold are galena (often richly argentiferous), blende, copper- and iron-pyrites; while the principal oxides are those of manganese, which are often very abundant in the City of Dunedin and Norfolk Mines, especially in the shallower workings.

From Tararu to Kuranui Creek the rocks consist of greenish-grey and dark-green or purple breccias and tuffs, which up to the present time have not been found to contain a single payable reef. The same or similar breccias form the ranges on the south side of Hape Creek, and in places they contain large masses of silicified wood, which would point to the existence of solfatara action during their formation. In the Kauaeranga Valley they are overlain by an enormous accumulation of trachytic tuffs and agglomerates, which are in many places intruded by dykes of trachyte and augite-andesite. In the higher part of the river-valley the latter are well exposed in the narrow, deep gorges, where they exhibit a beautiful columnar structure of huge hexagonal prisms. In all parts of the valley the tuffs contain veins and segregations of jasper, agate, chalcedony, as well as blocks of wood converted into wood-opal. At the foot of Table Mountain they contain intercalated beds of black and yellow-coloured shales and seams of impure brown coal. The presence of the latter proves the existence of a land-surface in this area during the period of eruption of the trachytic tuffs and lavas.

Gold-bearing Formation.

At the Kuranui or Shotover Stream we pass on to the gold-bearing formation of the Thames Goldfield, which extends without a break as far as Hape Creek on the south, and stretches in a north-easterly direction into the upper valleys of the Tararu, Puru, and Waiomo Streams, whence it extends northwards towards Mercury Bay. It is a noteworthy fact that wherever it is found it contains large, well-defined payable reefs. It consists of alternations of soft or moderately-hard decomposed andesites and bands of solid hornblende and augite-andesite lavas, which pass imperceptibly into indurated tuffs and breccias. The decomposed andesites generally possess a characteristic yellowish-brown or grey colour, and form the "kindly country" of the local miners; while the solid andesites and tuffs possess a greenish or dark-blue or purple colour, and are generally known as "hard country."

These alternating bands of soft and hard rock follow a general north-east course, and from the Kuranui Hill to the Waiokaraka Gully possess a north-west dip, at angles varying from 40° to 70°. From the Queen of Beauty shaft southwards the hard lavas assume an almost vertical position. The main reefs or lodes occur in the soft decomposed andesites, and follow their course and underlie. Of course, it must be clearly understood that the decomposed andesites show no stratification whatever, and the apparent strike and dip which they exhibit are imparted by the narrow hard bands or undecomposed cores, whose line of outcrop follows a north-east course. The reefs in most cases run parallel to the hard bars, and where these are steep, as in Kuranui Hill and between the Waiotahi and Karaka Streams, the reefs are steep; and where they are flat, as between the Moanataiari and Waitotahi Streams, the reefs are correspondingly flat or low-lying.

From the Thames foreshore the country rises to the north-east by a number of long, ascending spurs or ridges, which gradually converge and culminate at the Look-out Rocks situated on the watershed lying between the Karaka and Ohio Streams. The ridges and spurs appear in most cases to be formed by cores of the hard country, while the creeks have excavated their courses and valleys in the softer bands. The streams which diverge from the culminating point just spoken of are the Hape, Karaka, Waiotahi, Moanataiari, Kuranui, Shellback, Tinker's, Ohio, and Otonui.

Excepting in the Karaka area the hard bars or belts of rock are always subordinate to the soft "kindly country," both in width and extent. On the seaward side of the Moanataiari Fault and in the upper basins of the Moanataiari and Waiotahi, where extensive mining operations have been conducted for a great number of years, the alternating character of the soft and hard country is very marked and distinct.

Nature of the Rocks of the Gold-bearing Formation.

The true character of the gold-bearing rocks of the Hauraki Peninsula long remained a puzzle to all geologists who had examined this field, and it was only when the results of Professor Hutton's petrological work were published that this point was definitely determined. It is now known that they are the same as, and possess many of the peculiar features of, the volcanic rocks of the Comstock Lode and Washoe districts of North America, and the ancient mining regions of Hungary and Transylvannia in the Austrian Empire.

One of their most noticeable and remarkable characters is their proneness to rapid decomposition. I have already described how the blue indurated slaty-brecciated tuffs at Rocky Point pass through successive stages of alteration, until they assume a uniform yellowish-grey colour and an even texture.

This physical peculiarity is also true of the solid andesites, locally called "bluestone." On the summit of Una Hill there is, well exposed, a large dyke, or flow of hornblende-andesite, or dacite, which can be very plainly seen in the mines, and even more clearly on the surface, in various stages of decomposition, from a hard bluish or greenish-black rock to the grey-coloured "kindly country" of the miners. The solid andesite runs in a northerly direction, and crosses Karaka Creek about half a mile above the entrance to the gorge, and thence extends across the range to the Waiotahi, which it crosses at the waterfall a little above the upper level of the Fame and Fortune Mine.

Near the extreme top of Una Hill, on the slopes facing both Te Papa Gully and Block 27, the hornblende-andesite is exposed on steep bare places, where its manner of weathering can be studied with great advantage. It is seen to decompose in large spheroidal masses, composed of concentric exfoliating layers. In the centre of each sphere there is generally a hard undecomposed core of blue rock. These hard kernels are often washed out by the action of rain and running water, and collect in favourable places in large numbers.

The inner concentric layer possesses a dark-grey or purple colour; the next layer is dark-grey and white, speckled; while the succeeding layers pass from yellowish-brown to pale grey towards the outside. In the mines the graduations are equally well marked, but the decomposition does not assume the spheroidal form, which seems only to take place on the surface, where the rocks are exposed to atmospheric agencies, and free from superincumbent pressure.

The portion of Una Hill facing the lower end of the Karaka Gorge, as well as the gorge itself, is excavated in a tough greenish-grey chloritic rock, which was some years ago extensively quarried for the sea-wall of the railway embankment in Shortland and Grahamstown. This rock undergoes rapid alteration, as may be seen along the breastwork, and is, in consequence, not at all suitable for building purposes or works of a permanent character. It contains nests of calcite, gypsum, pearlspar, and chalcedony, as well as an abundance of chlorite in nests and veins. It was probably an augite-andesite, but its original character is difficult to determine on account of its altered state. At the entrance to the gorge, and at the quarry, it is seen to be associated with tuff, or ash materials, varying in texture from fine muds to coarse matter forming breccias. Judging from the irregular distribution of the fragmentary materials, I am inclined to think that these rocks are not true tuffs or breccias, but merely brecciated lavas.

In the Moanataiari, Waiotahi, Cambria, and Alburnia Mines the transition from the hard undecomposed lavas to the soft kindly country is often as well marked as on Una Hill.

The hard bars traversing the soft country in the May Queen, Trenton, Moanataiari, and other mines in the basins of the Moanataiari and Waiotahi Streams contain distinct layers of fine tuffs and coarser ashes, forming mottled breccias, but in most cases the matrix passes insensibly into solid andesite lavas. The hard belts of rock separating Dixon's, Sons of Freedom, Reuben Parr, and Golden Age reefs consist of compact, greenish-blue hornblende-andesite, which in places assumes a coarser texture, being black-spotted on weathered surfaces, with large crystals of hornblende. This porphyritic rock corresponds with the hornblende-dacite of Hutton. The undecomposed cores or bands of hard country on the seaward side of the Moanataiari fault consists principally of indurated tuffs and ash-beds or breccias of various degrees of texture passing into solid andesite lavas, of a hornblendic or augitic character. The two bars of so-called diorite bounding the reef system in the New Prince Imperial Mine is most probably an augitec or enstatite andesite.

Professor Hutton, in his paper "On the Rocks of the Hauraki Goldfields," divides the process of decomposition which the solid lavas have undergone into three distinct stages. First, the decomposition and hydration of the bisilicates—the hornblende and pyroxenes—resulting in the formation of chlorite and bastite, and the partial elimination of the liberated silica, iron, and lime; second, the destruction of the feldspars with the formation of carbonates and kaolin, accompanied by the bleaching and gradual removal of the secondary chlorite, and the alteration of the titaniferous iron into pyrites and the obscure mineral leucoxene; and third, the hydration and gradual removal of the iron-oxides, together with the leaching-out of the carbonates, leaving behind quartz, kaolin, leucoxene, and pyrites. Thus we find that the soft "kindly country" is composed entirely of secondary products. These stages, although of an entirely empirical character, are sufficiently distinct to be easily seen and proved by actual observation in many parts of the field. Becker, in his memoir on "The Geology of the Comstock Lode and Washoe District," states that the process of decomposition among the andesitic and diabasic rocks enclosing the Comstock Lode followed a sequence of stages somewhat similar to that which seems to have affected the gold-bearing rocks here.

In his report on the Geology of the Thames Goldfield,* Mr. Cox considers that the soft yellowish-grey gold-bearing rocks are still in their original condition, and are not the decomposed products of any other rock. He bases his opinion on the presence of undecomposed pyrites throughout their mass. This seems to me to afford but a slender basis for so important an argument, for it is a well-known fact that pyrites is always a secondary product, and in clastic rocks it is a common occurrence to find organic remains entirely replaced by this metallic sulphide. With regard to the pyrites disseminated in the Thames rocks, it is found in all but the more solid lavas, and it is pretty certain that it appeared at an early stage in the process of decomposition.

To the three stages distinguished by Professor Hutton may be added a fourth, in which the pyrites undergoes change first by alteration into the black ferrous sulphide, and then into the soluble ferrous sulphate. Large quantities of the latter salt are being deposited in the old dry workings in the Kuranui and Caledonia Mines, and in some of the levels the accumulation has been so rapid and extensive as to completely block up the underground passages. In the places where the waters charged with the ferrous salts issue into wet workings or drives, rapid oxidation takes place, and considerable deposits of the hydrated oxide are formed.

The third and fourth stages of decomposition to which the once solid andesites are still subject may be seen actually in operation in many of the mines where the harder bars are rendered accessible. The cold, acidulous waters from the surface are continually acting upon the carbonates of lime, magnesia, and iron, which were segregated in veins during the second stage of decomposition, with the result that they become highly charged with soluble salts of these substances, while large volumes of carbon dioxide are being continually liberated. This CO_2, in its turn, in conjunction with water, further reacts on the freshly-exposed surfaces of the feldspars and secondary chlorite in the already partially-decomposed cores of rock. Thus the progress of alteration goes round in a cycle, and in time will result in the complete decomposition, by leaching and oxidation, of the existing bars of solid andesites and tuffs. In the mines in the vicinity of hard bars, the country is saturated with CO_2 gas, which often interferes with the mining operations, especially during periods of low barometric pressure.

It is probable that after the volcanic forces which originated these rocks had spent themselves, sofatara action took their place, and continued in operation for a long time; and, in support of this, we still have the thermal mineral springs at Te Aroha issuing from the same class of rocks. The leaching-action of such thermal waters, no doubt accompanied by steam and acid vapours, would be more rapid and deep-reaching than the action of the surface-waters just described. The former existence of solfatara action would satisfactorily explain the presence of the grey, gold-bearing rocks, at depths far below the reach of surface-decomposing agents. At the present lowest level of the old Queen of the May shaft, situated in Waiokaraka Gully, the grey decomposed andesite, at a depth of about 400ft., is identical with that found at the surface. The same fact is seen in the low-level tunnel of the Occidental Mine at Una Hill, where the grey "kindly country," highly charged with pyrites and veins of pearlspar, is found at a point in the centre of the hill at least 700ft. from the surface of the nearest point. Numerous examples of the same fact can also be obtained in the Queen of Beauty, New Prince Imperial, Waiotahi, and Cambria Mines, where the grey, gold-bearing country has been carried down from the surface to depths varying from 300ft. to 748ft. below sea-level.

The soft, gold-bearing rock, or "kindly country," is now acknowledged by all the leading European and American petrologists to be a decomposed andesite; but for many years there was much discussion and controversy as to its true character and proper designation.

In 1868 Von Richthofen adopted the distinctive term "propylite" for the grey, decomposed, ore-bearing rocks of the Comstock Lode, a name which was subsequently adopted by the officers of the United States Geological Survey.

In 1876, the results of Dr. Zirkel's microscopic examination of the North American rocks was published, and in this work he endeavoured to justify the retention of the term "propylite" as a distinct type of rocks, although he went so far as to admit their association with the Tertiary lavas.

In the following year Professor Rosenbusch refused to accept the name "propylite" as a distinctive group, but classed many rocks known as such with the andesites.

In 1879 Dr. Doelter showed that the Hungarian rocks, which possessed the peculiar features held by Von Richthofen and Zirkel to be characteristic of the propylites, could be seen to pass insensibly, by a gradual process of alteration, into ordinary andesites. Shortly after this Doelter's view was strongly upheld by Rosenbusch; and in the same year Dr. Wadsworth very forcibly insisted that the distinction between the propylites and andesites could not be maintained in the case of the North American rocks.

In his "Geology of the Comstock Lode and Washoe District," 1882, Mr. G. F. Becker states that the grey decomposed ore-bearing rock which corresponds with the "kindly country" of the Hauraki goldfields could not be regarded as a distinct group of rocks, but only as a distinct *facies* or *habitus* of the andesitic lavas. The microscopic examination of a large number of the rock-specimens obtained in the deepest workings, and during the construction of the Sutro Tunnel, enabled Mr. Becker to show that by the gradual alteration of their constituent minerals the hornblende- and the augite-andesites gradually acquired those characteristics which had been held to be peculiar to the propylites.

In 1886 Professor Rosenbusch accepted the term "propylite," not, however, as indicating a distinctive group of rocks, as originally contended by Richthofen and Zirkel, but only as a convenient name serving to distinguish a well-marked and interesting pathological variety of the andesitic type of rock. The term "decomposed andesite" is inconvenient and clumsy, and I think the name "propylite" might with propriety be adopted by all New Zealand geologists in the restricted sense proposed by Rosenbusch. I shall hereafter in this paper speak of the soft yellowish-grey decomposed andesites as propylites.

* Geological Reports, 1882, p. 4.

Origin of the Gold-bearing Rocks.

Judging from the character of the breccias at Tararu Beach, and the more or less rudely stratified structure of the tuffs in many parts of the peninsula, I am inclined to think that the volcanic eruptions which originated the rocks of the Thames Goldfield were submarine, and most probably took place in shallow seas studded with rock-girt islets. The occasional presence of masses of silicified wood in the Hape Creek breccias clearly indicates the proximity of dry land. But while subaqueous eruptions were active in one case, subaerial volcanoes were pouring out vast deposits of fragmentary ejecta, accompanied by great streams of lava, in others. On the western slopes of the main range lying between Coromandel and Cabbage Bay the great volcanic breccias contain intercalated shales and thin seams of fine bituminous coal, composed of a terrestrial vegetation, thus proving that the eruption in that area took place on dry land. The same conditions are also indicated near Paeroa, where a thick deposit of black coaly shale, containing irregular layers of brown coal several inches thick, is intercalated among coarse volcanic breccias.

There is an entire absence of visible volcanic vents in this district, but the prominent masses of andesitic lavas and breccias in the high country at the source of the Karaka may mark the sites of ancient points of eruption. The widespread character of the volcanic ejections, extending throughout the whole length of the peninsula, would lead to the conclusion that the eruptions took place along a great fissure-rent, possessing many points, or *foci*, of intense activity, a feature so strikingly illustrated during the volcanic eruption at Tarawera in June, 1886.

Age of the Gold-bearing Rocks.

In the Thames district, the gold-bearing rocks are found resting directly on a highly denuded surface of the Palæozoic slaty shales; and, since they contain no distinct fossils themselves, their age cannot be determined here, although the presence of dicotyledinous leaf-impressions in the coaly shales imbedded in the breccias at Paeroa and Tapu affords unmistakable evidence of their Tertiary age. But the only direct and satisfactory evidence of their age is to be found on the coast-line between Coromandel and Cabbage Bay. There, at Waitete Bay, a small isolated patch of fossiliferous strata of Cretaceo-tertiary age is found resting on a denuded surface of Palæozoic slaty shales and greywackes. The younger series consists of a thick stratum of coarse sandstone-conglomerate resting on the slaty rocks. This is followed by marly greensands, in turn overlaid by a hard impure shelly limestone, which closes the series. A few chains back from the beach the whole series is overlaid by the gold-bearing series, consisting there of coarse breccias, with coaly shales, indurated tuffs, solid andesites, and propylites containing gold-bearing quartz-veins. The volcanic rocks are therefore younger than the shelly limestone of Lower Eocene age, and, judging from the presence of the ash-bed in the Waitemata series, on the shores of the Waitemata Harbour, I am of the opinion that the eruptions began in Upper Eocene times, and continued down to the Middle Miocene period. It is interesting to note that the North American andesites are considered of Lower Miocene age, as also are the andesites and propylites of Hungary and Transylvannia.

High-level Terraces.

On the north side of the Kauaeranga River, in the direction of Totara Point, there is a high, broad river-terrace, composed of well waterworn gravels and white quartz-sands. The materials forming this terrace were transported by the river when it flowed at a higher level than at the present time.

The flat on which Irishtown is built, and the undulating and sloping ground in the area known as Block 27, are occupied by the remains of the old high-level terrace formed by the joint action of the Karaka and Hape Creeks. The original level of this old terrace is best seen at Irishtown, at the lower end of which it terminates abruptly, at a point overlooking the Queen of Beauty shaft. Its height here is about 175ft., and an examination of its face shows that it consists of numerous alternating horizontal layers of clay, sand, and gravel, with occasional bands containing large rounded boulders of decomposing andesite.

On the south side of the Karaka the original level of the old terrace can only be traced in a few places, the small streams which descend from Una Hill having excavated it into broad, undulating spurs, which are now largely built upon. A portion of the old Hape Creek terrace is well preserved at Mount Pleasant, and in the road-cuttings in that neighbourhood the bedded character of the materials is very clearly seen. Both in the Karaka and Hape Creek areas the terrace-clays often contain numerous large subangular masses of solid andesite.

A small patch of the Waiotahi old high-level terrace is still preserved opposite the Cambria battery, at the point where the stream issues from its valley.

The Moanataiari Fault forms the north-east boundary of the terrace-materials along the foot of Una Hill, but no evidence can be obtained to show whether the Great Fault is older or younger than this Pleistocene gravel and boulder-formation, but at present I favour the opinion that it is of somewhat older date.

The Alluvial Flat, and Floor of the Harbour.

The alluvial deposits on the foreshore have been exposed by different shafts and borings to a depth of 90ft. from the surface; and by levels driven from the New Prince Imperial and Piako shafts to a depth of 300ft. or 400ft. A shaft sunk in Shortland in 1868 passed through 2ft. of surface-soil, 10ft. of shelly sand, 68ft. of blue and yellow clay mixed with boulders of andesite, and 10ft. of pumice-sand. The actual depth of pumice-sand was never determined. The information disclosed by the seaward levels shows that the floor of the old harbour is occupied by a great boulder-formation, composed of materials similar to those forming the high-level terrace behind Shortland. For a number of years no mining operations have been carried on from the shafts on the foreshore in the direction of the harbour, so that the data relating to the existence of the supposed "beach-slide" or fault is of a very meagre kind. In consequence of this, it is impossible to

definitely decide whether the boulder and clay formation met with in the floor of the harbour is really a faulted portion of the Shortland terraces, or merely the accumulated waste of the back-country.

I have already pointed out how the courses of the streams which drain the goldfield's area traverse the softer gold-bearing propylites, and, when we examine the wide deep valleys which have been excavated by these streams, it is only fair to assume that alluvial deposits of great wealth must rest on the floor of the harbour below the great boulder-formation just described. At what depth this alluvial gold lies is at present a matter of mere conjecture; but when the working of the deep levels is an accomplished fact, and seaward drives are constructed at different levels, its position will be determined beyond all question of doubt; and there is just as little doubt that, when found, means will be adopted to work it successfully.

The Great Faults which displace the Reefs.

The Thames Goldfield is traversed by two great faults of the highest scientific and economic interest. Their scientific interest lies in the freshness and clearness of the evidences which characterize their courses, both on the surface and in the mines; while their economic importance is to be found in the displacements of the gold-bearing reefs which they have caused, and in this respect they play an important part in the distribution of the gold.

The best known and most important of these is the Moanataiari Fault, which runs almost at right angles across the trend of the reefs. Its surface-line of outcrop crosses Hape Creek immediately below the gorge on that stream, and then strikes along the foot of Una Hill till it reaches Karaka Creek. Thence it proceeds up Collarbone Gully a distance of nearly 10 chains, whence it crosses the spur into Waiotahi Creek. From there it runs across the dividing-spur into the Moanataiari Valley, whence it follows a north-west course to the head of Kuranui Creek. From that point it follows a more westerly course, and reaches the sea a few chains north of the mouth of Shellback Creek.

The course of this remarkable fault is marked on the surface by a distinct line of depression, which can easily be traced by the unaided eye. On its north-east or upland side the spurs and ridges which it crosses rise abruptly to a height of 300ft. or 400ft. above the general level of the corresponding spurs which descend towards the foreshore. This feature is well seen by a study of the section from the foreshore to Punga Flat. It "hades" or underlies to the south-west—that is, towards the harbour, at a uniform angle of 45°. This seems a very flat angle of inclination for so great a fault, but I have verified it in many places by personal observations, and by reference to the working-plans of the mines situated on its course. Where the fault crosses hard rocks, the striations and slickensides on the surface are often as fresh as if the faulting or sliding had only taken place yesterday.

The enormous friction and pressure due to the sliding on the walls have crushed and shattered the rocks for a considerable width on each side of the fracture, and caused the formation of bands of stiff impervious clay lying parallel to the original line of fissure. In the Moanataiari low-level adit, where the fault is cut about 30ft. above sea-level, the country is crushed and disturbed for a distance of 40ft. or 50ft.; and where this point was first reached when the tunnel was being constructed the influx of water was so great that all mining operations had to be suspended for some considerable time. It is also a memorable fact in the history of the goldfield that when the north-east cross-cut, from the 640ft. level of the Big Pump shaft, reached the main slide, a mass of soft irresistible plastic clay rolled down the drive with great velocity, causing the workmen to fly for safety. The fault thus acts as a great underground watercourse or channel, dividing the goldfield into two distinct parts—a seaward portion and an upland portion; and it is a noteworthy circumstance that this remarkable geological feature is constituted, by an Act of Parliament, the eastern boundary of the area under the control of the Thames Drainage Board.

On account of the absence of stratified deposits, or any well-marked or distinctive geological horizons, it is impossible to accurately determine the amount of the lateral and vertical displacements of the rocks and reefs caused by this great earth-fracture or crack. When the reefs on the seaward side reach the fault they are suddenly cut off, and their displacements are so great that up to the present time not one of them has yet been recovered on the foot-wall or upland side. The only available data of any value is obtained by measuring the difference of altitudes of the spurs on each side of the fault. I have taken a number of aneroid altitudes, and find that the difference of level varies from 280ft. to 350ft., and, allowing for the waste of denudation that has taken place since the origin of the fault, I think that 400ft. will be found to be not far from the actual amount of vertical downthrow. Calculated from this basis, and using the known dip of the reefs and their intersector in different parts of the field as constant factors, it is found that the apparent lateral displacement or "heave" for the steep reefs in Kuranui Hill would range from 150ft. to 185ft. to the left or north-east; in the area of flat-lying reefs between the Moanataiari and Waiotahi Streams, from 350ft. to 420ft. to the north-east; and in the Queen of Beauty area, where the reefs are vertical or steeply inclined to the south-east, the displacement would be from 0ft. to 185ft., the heave in this case being to the right hand or south-east. The flatter the underlie of the reef the greater will be the heave, and, conversely, the nearer the reef approaches the vertical position the less the heave, and when truly vertical there will be no heave, however great the amount of throw may be. Thus, if we follow a reef, on the seaward side, up to the Great Fault in the Kuranui and Waiotahi areas, it will be necessary to cross-cut to the left if we wish to recover our lode on the upland side of the fault; and the length of the cross-cut to be constructed will vary with the inclination of the reef.

Along its whole course the Moanataiari Fault "hades" towards the harbour at an angle of 45°, and in the Kuranui Hill area the reefs die out as they descend into the hard country; hence it followed that when the sliding or faulting movement took place, in addition to the apparent heave and throw, the ends of the shallow reefs were pulled asunder or apart. In other words, the fault acted as a

GEOLOGICAL MAP
OF THE
THAMES GOLDFIELD.

BY
JAMES PARK. F.G.S.
1894.

FIRTH OF THAMES

Section

FUNGA FLAT

COLLARBONE

Otara Creek

Tararu Stream

Tanker's Ck

Waiokaka Creek

Waiohinga Creek

ROCKY POINT

TARARU

Tararu Stream

Shellback Ck

MOANATAIARI

Kuruwai Ck

Moanatairi Ck

FAULT

HAHA

Golden Age Reef

Big Reef

Waiotahi Creek

Big Reef

Kuruwai Hill Stockwork

Moanatairi Stockwork

Caledonia Reef

Caledonia Stockwork

Line

GRAHAMSTOWN

Karaka Stream

Line

HAGUE

SMITH REEF

MAIN REEF

Tom Cutting

UMU HILL STOCKWORK

Hapo Creek

ADELAIDE REEF FAULT

Karaka

IRISHTOWN

Line

BLOCK 27

SUPPOSED FAULT

SHORTLAND

BEACH

PARAWAI

Waiwhakaruinga R

— SECTION FROM ROCKY POINT TO TOTARA POINT. —

Rocky Point
Tararu Stream
Shellback Creek
Moanatairi Fault
Kuruwai Creek
Mowatairi Tunnel
Big Pump
Victoria
Prince Imperial
Saxon
Exchange
Queen of Beauty
Bird in hand No 1
Vanguard
Bird in hand No 2
Mako
Karaka Creek
Prospecting Shaft
Hapo Creek
Waiwhakaruinga River
Sea level

— SECTION FROM FORESHORE TO PUNGA FLAT. —

Mako Shaft
South Slide or Fault
Moanatairi Fault
Golden Age Reef
Collingwood Fault
Punga Flat
Sea level

REFERENCE.

1	RECENT. Alluvial Flats & swamps, beach sands &c.	4	Hornblende andesites and Tuffs, forming the "hard country" of the miners
2a	PLEISTOCENE. High level gravel terraces	5	Decomposed Andesites & Tuffs, forming the soft or "kindly country" of the miners
2b	" Formation of boulders, sand, mud &c below sea level	6	Andesite breccias, agglomerates and Tuffs, seldom containing gold bearing reefs
2c	" High level terraces of boulders, gravels, sands &c	7	MESOZOIC. Blue slaty shales
3	Trachyte & Andesite agglomerates & Lavas	8	" Yellowish-coloured mudstones

Gold bearing formation

— SCALE FOR PLAN AND SECTIONS. Horizontal and Vertical. —

great sloping plane, possessing an inclination of one in one. If the total depth of the reef were represented by the total throw, then for every foot of throw there would be 1ft. of horizontal displacement parallel to the line of movement—that is, at right angles to the trend of the fault—for every foot of vertical throw.

The effect of the fault on shallow lodes would be that, on the upland side, the reefs would not reach the line of fault, except in cases where the depth reached by the lode were greater than the total throw caused by the fault. For this cause, the Dixon's, Sons of Freedom, and Reuben Parr main lodes have not been traced on the surface to the fault, but end in strings and clay-heads in the hard country, as shown on the map.

In the case of reefs which live down to a greater depth than the total vertical throw of the fault, their severed ends will be found to abut against the fault on both sides, but, as I have already stated, the corresponding parts of the ends will not be found opposite to each other, on account of the throw causing an apparent lateral heave.

Applying this law to Kuranui Hill, it will be found that if we drive on a lode up to the fault, and wish to recover it beyond, on the foot-wall side, it will first be necessary to extend our drive in a straight line some distance beyond the surface-line of the fault, and then turn to the left and cross-cut, at right angles, a distance varying from 150ft. to 185ft., according to the dip of the lode. In the case of a shallow lode it will be necessary to put up a rise from the end of our cross-cut to recover the lost lode. In the Waiotahi area, where the lodes are deep-reaching, they would be recovered by simply cross-cutting to the left.

The Age of the Moanataiari Fault.

The exact period at which this great fault originated is not easily determined, but its comparatively recent date is established by a number of its physical characters and peculiarities. Its course on the surface is still marked by a distinct line of depression, and on its upland side there is a very distinct modification of the physical features of the country, showing that the ever active and unceasing agencies of subaerial denudation have not had time to destroy and obliterate the evidences of its vertical displacement. Again, in places where the fault has been cut in the mines, it has been found to contain masses of rotten wood, fern-roots, and other partially-decayed vegetable matter entangled in the soft clays and "pug" lying on its hanging-wall. In places where it intersects rock-masses, the faces of the rock often present very fresh slickensides and striations.

When proceeding up the course of any of the streams which drain the goldfield it is seen that at the point where the stream reaches the fault the valley suddenly contracts to a narrow gorge. This is caused by the fault intersecting the valleys at right angles to their general trend, and admits of a very simple geological explanation. It is well known that when a fault crosses a syncline of stratified rocks the lines of outcrop of the strata or beds are thrown inwards or outwards according to the direction of the dip of the intersector. In the present case, the sides of the valley represent a syncline, and as the fault "hades" towards the harbour the downthrow is, in consequence, in that direction. The immediate result of this is to bring, by faulting, a wide part of the valley opposite a narrow part, this narrow part forming the present gorge. The existence of this interesting feature is another proof that the denuding agencies have not been in operation long enough to excavate the valley to a uniform width since the date of the fault. The whole of the evidence, when taken together, seems to point to the very recent origin of this great fault, and I am inclined to put it in the Newer Pliocene or Older Pleistocene period.

Collarbone Fault.

This fault is only second in importance to the great Moanataiari Fault. It joins the latter a few chains from the mouth of Collarbone Creek, and thence follows the strike of the Nana Reef to the low saddle overlooking the Waiotahi Stream. Beyond this its trend is somewhat obscure, but at Punga Flat the Golden Age Reef is heaved a considerable distance by a fault which runs in a parallel course, and, with the amount of data available at the present time, I am of the opinion that this fault is its northerly continuation. From Punga Flat it runs into Ohio Creek, where it abruptly terminates the Sylvia Reef in the workings passing south-westwards. In the lower part of Collarbone Creek its course is well marked by slickensided and striated rock-surfaces, and in the Nana drive of the St. Hippo Mine by great masses of slickensided clay and "pug." It "hades" to the south-west at angles varying from 45° to 65°, but in a few places it is even steeper. It has heaved the reefs it crosses to the left or north-east.

Beach Slide or Fault.

Besides these two great faults, there is what is locally termed the "beach slide." It is found that in driving from the shafts on the foreshore towards the harbour a loose formation is met with, composed of sands, gravels, and harbour muds, mingled with large rounded boulders of andesite and tuff, and occasionally with sea-shells and pieces of rotten wood. This has led to the belief that the country is cut off by a fault in this direction. A reference to the working-plans of the mines situated on the foreshore shows that this supposed slide follows all the contours and windings of the present line of cliffs running behind the township. The distance, also, at which it has been cut at the different levels shows that it descends at an angle of about 45°. For the present, I am inclined to regard this so-called slide as simply the face of the old submerged line of sea-cliffs, the appearance of a fault being caused by driving out of the country into the old submerged harbour.

In most of the mines the reefs are intersected and disturbed by many small faults and cross-courses, locally called "breaks." These seldom cause displacements more than a few feet in extent, although heaves of 30ft., or even 50ft., are met with in some of the mines. In age, many of these appear to be contemporaneous with, or only of slightly latter date than, the reefs they intersect. They are generally regarded as a favourable indication for the occurrence of rich patches of gold at

the point of junction with the reef. Past experience has proved beyond all doubt that they have, in some way not yet satisfactorily explained, exercised a powerful influence on the formation and distribution of the precious metals. It is, therefore, of the greatest importance that their direction, underlie, and points of contact with the reefs should be accurately marked upon the working-plans and sections belonging to the mines, so as to enable the mine-manager to intelligently develop his mine, and trace the shoots of gold.

In the Kuranui Hill the reefs are caused by several faults of more recent date than those just described. A very clearly-defined fault follows the face of the line of cliffs behind the Kuranui and Saxon batteries. It "hades" towards the Moanataiari Fault at an angle of 75°. It can be traced on the surface as a distinct line of fracture from the top of the ridge immediately above the entrance to the Moanataiari adit-level to the open workings on the face of the hill, and thence along the lower slopes to the Moanataiari Creek, near Tookey's old shaft.

About 1,000ft. further to the north-east, on the line of No. 3 Reef, another small fault exists, running parallel to the fault at the mouth of the long tunnel, and dipping in the same direction at an angle of about 45°. Still proceeding north-east, another fault is met with, intersecting the same reef. It "hades" towards the fault last described, and seems to spring from the hanging-wall of the Moanataiari Fault, which is not far distant. The angle of dip is very flat, being not more than 35°.

Geological History of the Hauraki Peninsula.

From the foregoing facts we can gleam an insight into the past geological history of this interesting region, and at the same time follow the sequence of events which has resulted in the construction of the present physical features of the Peninsula.

During the whole of the Secondary epoch this area was occupied by a deep, still sea, devoid of islands or islets. With no dry land to waste, no sediments were formed during this long period of time. New Zealand throughout the Secondary epoch—like Great Britain—seems to have been singularly free from volcanic activity and all great earth-movements. But at the close of the Cretaceous period the land in this area began to gradually emerge from the sea, and an island of large size appeared to the north-east of the present site of Coromandel. The ever-active agencies of denudation at once began to wear away the dry land, and the spoil was carried to the sea by numerous streams and rivers. After a period of rest, the land began to sink, and the peaty deposits which had accumulated on the low-lying marshy shores of the island were soon submerged, and in their turn became covered with coarse gravels, sands, and clays, carried seaward by the streams which descended to the coast-line. The land still continued to sink, and, as the sea encroached, true marine deposits were formed above the fluviatile materials, and, as shelly limestones, closed the sequence of the coal-measures, and marked the complete submergence of the dry land.

But with this disappearance the quietude which New Zealand had so long enjoyed was rudely broken. Submarine volcanic eruptions of the most violent and widespread nature now took place. Great fissure-rents opened in the floor of the ocean, and poured out vast quantities of ashes and floods of fiery lavas, which soon became piled up, until many of the volcanoes reared their heads above the water. This stupendous outburst took place in Upper Eocene times, and is marked by a characteristic fossiliferous ash-bed in the Waitemata series, whose sediments were accumulating at this time in the quieter seas in the western Hauraki region. This bed, well known as the "Parnell Grit," consists of sea-borne ashes and mud, and occasionally angular fragments of solid hornblende- and augite-andesite lavas, often several inches in diameter.

After the pent-up forces had spent themselves in the first great paroxysm there was a period of rest from volcanic activity, during which vegetation established itself on the muds and ashes washed into the low ground by the streams draining the slopes of the newly-formed volcanoes. But the land was in a continual state of tremor, and the oscillations too frequent to permit the continued growth and accumulation of sufficient vegetation to form workable seams of coal.

The cessation of volcanic activity was of short duration. The plutonic forces burst out with renewed energy. The forests were devastated and utterly destroyed, and covered by hundreds of feet of ashes and solid lavas, first of a semi-basic, and then a trachytic character. The embedded trees in many cases were converted into wood-opal by the petrifying action of the thermal springs, which appeared when the volcanic forces had became once more dormant.

The land along the line of eruption now began to emerge from the sea, but the process was accompanied by violent earthquakes and convulsions of the land. The enormous strain following the consolidation and cooling of the vast accumulation of volcanic ejections, no doubt aided by the settling of the crust, due to the great excavations made below, originated numerous deep-seated parallel fissures running in a north or north-east direction. The expiring volcanic forces still manifested themselves in solfatara action of an intense kind along these fissures, which probably coincided approximately to the general trend of the original line of fissure-rent.

The thermal waters, steam, sulphuretted hydrogen, and other acid vapours soon began an energetic attack upon the amphiboles, pyroxenes, feldspars, and other complex silicates forming the matrix of the semi-basic lavas. The silica became separated from its bases, and soluble alkaline silicates were formed, as well as soluble salts of the metallic bases. After the leaching had thus proceeded for a long time, and the solfatara action had become feeble, the alkalies found new combinations, and the liberated silica, in the form of quartz, became segregated in the cracks and fissures, and distributed in fine grains throughout the mass of the leached lavas. While the changes which caused the liberation of the quartz were in operation the fissures, now charged with alkalies as alkaline sulphides, became great voltaic cells, and the theatre of electro-chemical action. The basic solutions were decomposed and their metallic contents electro-deposited, the base metals and a portion of the silver as sulphides; and the gold, together with the greater portion of the silver, as a metallic alloy. The formation of the quartz and the deposition of the metals was thus carried on simultaneously in the fissures, by reactions, which were the complements of each other.

During this period of solfatara action, and for a long time after, the dry land was ever subject to the denuding and degrading agencies of rain and running water. The present valleys were then being excavated, and the waste transported to the sea, where it was spread out on the floor by the sorting-action of the water.

Since the second great outburst, recorded above, which culminated in the formation of the massive trachytic mountains which occupy the higher and more inland portions of the peninsula, as well as the outlying islands in Coromandel Harbour, this area has enjoyed complete repose from all volcanic manifestations. But not so the other parts of this island. In Newer Pliocene times the central portion of this island became the scene of the most widespread and devastating eruptions that have ever taken place in New Zealand. The region from Ruapehu to Tauranga was occupied by a chain of great crater-lakes filled with molten magmas, from which liquid streams of fiery acid lavas were projected over the country for hundreds of square miles. At this time were formed Ruapehu, Tongariro, Pihanga, Tauhara, Horohoro, and the solfatara-scarred mountains of the Tarawera region. The light frothy ash or pumice of the acid eruptions, either wind- or water-borne, was spread as a continuous sheet over half of the Island. At Shortland the pumice deposit is only 10ft thick, but in the upper Thames Valley, and in the Upper Waikato, it is often found hundreds of feet deep, especially near the centres of eruption.

The solid rhyolites, often much brecciated, reached as far north as Paeroa, Awaroa, and Waihi, filling in and levelling the old valleys excavated in the older volcanic rocks. Thus, at Waihi, we find the well-known Martha Hill and its productive lode surrounded by a great thickness of grey rhyolitic breccias and lavas, which appear to have originated in the direction of Tauranga.

It was probably during these Pliocene eruptions that the great earth-movements took place which resulted in the formation of the faults which traverse the Thames Goldfield. These faults cross the lines of the reef systems transversely, and their courses approximate to the direction of the initial line of eruption, which no doubt followed the line of least resistance.

The Gold-bearing Reefs.

The gold-bearing rocks consist, as we have seen, of grey or yellowish-grey or iron-stained propylites, which occur in great bands or belts, separated from each other by hard bars or cores of solid andesite lava, or indurated tuffs passing into breccias. These bands of propylite, or "kindly country," extend in a N.E. to S.W. direction, and dip, as indicated by the hard country, in a north-west direction in that portion of the field lying between the Kuranui and Karaka Streams. The major lodes are contained in the propylites, and follow the same north-east course, and generally possess the same underlie. They belong to the segregated class of lodes. Each band of propylite contains a distinct system of reefs possessing its own characteristics and peculiarities.

On the seaward side of the Moanataiari Fault, the main reefs, as far as the Karaka, are Barry's, Shotover, Moanataiari No. 9, Caledonia Nos. 1 and 2, Waiotahi, Mariner's, Saxon, Queen of Beauty, and Vanguard. In the southern portion of the field no mining has been carried on, so that it is impossible for me to state what reefs exist in that area.

On the upland side of the fault the best-known main reefs are the Sylvia, Dixon's, Sons of Freedom, Reuben Parr, Golden Age, Waiotahi, Nana, Adelaide, Moa, Duke's, Loyalty, Dayspring, Occidental, Magnolia, Jupiter, and Hague-Smith.

On account of the great dislocation of the country caused by the Moanataiari Fault, it is difficult to correlate the reefs on the seaward side with those on the upland side; but, judging from similarity of lode-matter, underlie, and position, I am inclined to connect Barry's Reef with Dixon's; Sons of Freedom with the Shotover; Reuben Parr with Moanataiari No. 9; Caledonia No. 1 with the Golden Age; and the big reef in the Waiotahi and Cambria Mines with the Waiotahi Reef exposed at the Devil's Elbow.

The Mariner's, Saxon, and Queen of Beauty Reefs have never been recovered or recognised beyond the fault; but I am of the opinion that they will yet be found in the massive spur lying between the Waiotahi and Collarbone.

Systems of Reefs on the Seaward Side of Fault.

Shotover Reef.—It was in this reef that the first rich patch of gold was found at the Thames. The reef follows the bed of Kuranui Stream, and possesses an underlie to the north-west at very steep angles—in places almost vertical. It varies in width from 2ft. to 9ft., but in Hunt's old claim the reef and adjoining country were quarried out to a width of 25ft. or 20ft. It was traced from the beach to the fault, but did not live downwards more than 60ft. or 70ft., being cut off by the hard mottled breccias towards which it dipped. Barry's Reef crops out on the opposite side of the stream, and underlies towards the Shotover Reef, as if it would join it at no great depth from the surface.

Between the Shotover and Moanataiari, the Kuranui Hill is traversed by Duke's, All Nations No. 3, and Moanataiari No. 9, all well-defined lodes, varying from 1ft. to 7ft. in thickness. They all underlie to the north-west at very high angles. Very little of them now remains to be worked, as they have been stoped in most cases right up to the surface. They all proved very remunerative, and in their courses received numerous small branching leaders and "droppers," some of them very rich. In some places Kuranui Hill is so numerously intersected by small gold-bearing quartz-veins that it was for some time successfully mined as a "stock-work." So far as I can gather, none of the reefs already described have been found payable below sea-level, except Duke's Reef, supposed to be a hanging-wall leader of No. 9 Reef, which yielded the rich patch at 80ft. below the tunnel-level.

Caledonia No. 1.—This reef was first worked in the Manukau Mine, and was there from 4ft. to 5ft. thick. In the Golden Crown Claim it opened out to 10ft., containing in the centre a "horse" of country about 2ft. thick. Towards the Caledonia boundary it dwindled down to 9in., but towards the south it gradually opened out to 18in., and soon after passing the boundary reached

8ft. in width. Opposite No. 2 shaft it suddenly widened to 18ft., and at the 210-foot level, 150ft. below sea-level, where the great bonanza was found, it was excavated a width of 30ft. It possesses a north-west dip at an angle of 40 degrees. In the Manukau Claim the outcrop was about 220ft. above sea-level, and, as payable gold has been obtained as low as the 350-foot level—that is, 290ft. below sea-level—it follows that the reef for a vertical distance of 510ft. has yielded payable gold.

Caledonia No. 2.—This reef was first discovered in the New Golden Crown Mine, below No. 1 reef. It dips north-west at an angle of 45 degrees. It is a strong, well-defined lode, varying from 4ft. to 12ft. in thickness. Along their course Nos. 1 and 2 reefs come together and separate several times, but they finally cross each other in the Manukau ground, and thence pursue a separate, although almost parallel, course to the fault. The quartz in this reef is generally harder and more compact than that in No. 1.

Waiotahi Reef.—This large reef crops out on the left side of the Waiotahi Stream, nearly opposite the battery of that name. It traverses the Waiotahi and Cambria mining leases, and can thence be traced along the surface as far as Punga Flat. In many places it stands up as a distinct wall of quartz. It dips north-west at a very flat angle, seldom over 45 degrees, and everywhere receives a great many foot-wall leaders, often very thin, and so numerous as to form a perfect network of veins. These small leaders have been very largely worked in the Waiotahi, Cambria, and Fame and Fortune Mines, and up to the present they have proved more remunerative than the main lode itself. It maintains an average width of about 12ft., but in places it expands to 30ft. or 40ft. In the Fame and Fortune Mine, where it crosses the dyke of hornblende-andesite, which forms the waterfall on the Waiotahi at the Big Bend, it narrows down to about 2ft., but it widens again as soon as it gets clear of the hard country. This is one of the champion lodes of the goldfield, and so little mining has been done upon it, that it may be said to be practically intact. The great mass of its quartz is, however, very low-grade, but, with specially favourable facilities for transit of the ore, and cheap crushing, it should be made to yield payable returns for many years. I have made the most careful inquiries, and find that its value, as determined by many large battery-tests, varies from 5s. to £1 10s. per ton, with richer patches at the intersections of the small leaders or "droppers." In the Fame and Fortune Mine this splendid reef has been stripped for over 1,000ft., and shows a clean, well-defined foot-wall. It has been proved to a depth of 400ft. below sea-level and 1,200ft. above, thus showing that it possesses great persistency in depth, as well as in linear extension. The quartz is hard and of a bluish-grey colour. If often contains "vughs," or drusy cavities, lined with fine crystals of stibnite or iron pyrites; and throughout its whole mass it contains a considerable percentage of the latter sulphide. The foot-wall "droppers" generally traverse the country at steeper angles than the main reef. They vary from a mere thread to 6in. in thickness, and have often proved very rich. At the points where the richest stone is found, the quartz is often encrusted with thin layers and specks of pyrargyrite, the dark ruby-silver, and also copper pyrites.

Mariner's Reef.—This reef is situated in the New Prince Imperial line of country. It dips north-west at an angle of 45°, and varies in size from 2ft. to 20ft. Where cut in the south cross-cut from the 640ft. level of the Big Pump shaft, it was about 22ft. thick. It has yielded large quantities of gold. What is known as No. 2 reef, in the same mine, varies from 6in. to 2ft. in width, and was very rich, having yielded most of the gold which enabled the New Prince Imperial Company to declare dividends for several years. Payable gold was carried to a depth of 500ft. below sea level in this mine, but the best gold was obtained between the 243ft. and 492ft. levels. Proceeding north-eastward along its course, the Mariner's Reef pinches out against the hard belt of andesite and tuff, which caps the Trenton ridge and sends down a wide prolongation between the May Queen and Cambria Mines, and another in the direction of Crawford's shaft, near the fault. The consequence is that it does not reach the surface on the seaward side of the fault, but it may be found to plunge below the hard country and descend to a great depth.

Saxon System of Reefs.—There are two main lodes in this line of country, known as Nos. 1 and 2 respectively. They follow a north-east course. Both are inclined at very high angles, but they dip in opposite directions, No. 1 having a distinct south-east dip and No. 2 a north-west dip. Towards the north-east they gradually come together, and ultimately unite in the old Exchange lease. The width of No. 1 is from 3ft. to 10ft., and of No. 2 about 2½ft. Both are strong lodes, and have yielded thousands of ounces of gold. From the hanging-wall of No. 2 spring two rich leaders, locally known as "hanging-wall leaders Nos. 3 and 4." Leaving the hanging-wall of No. 4 there is a small "dropper" called the "specimen-leader, which was exceedingly rich while it lasted. After their junction the main lodes pursue a north-east course until they end in clay-strings in the hard Trenton belt just described above. As in the case of the Mariner's Reef, I think it probable that the united lodes may descend below the hard country, and eventually reach the Moanataiari Fault; but, should the Trenton breccias and andesites occupy the site of an old vent it is hardly likely that any of the reefs between the Waiotahi and Waiokaraka will reach the fault. In the Saxon country gold has been obtained from the reefs from the surface down to No. 6 level; but there can be no doubt that, so far, the most payable returns have been got from the 274ft. to the 386ft. level.

Queen of Beauty System of Reefs.—There are two main lodes in this belt of gold-bearing propylite known as No. 1 and No. 2. They are almost vertical, but No. 1 underlies to the south-east at an angle of 75°, and No. 2 to the north-west, that is towards No. 1, at the same angle of inclination, the result of this being that they meet on the beach side of the shaft at No. 4 level, below which they descend as one reef, keeping the south-east underlie of No. 1. The average width of No. 1 is about 5ft. and of No. 2 10ft., the latter, however, sometimes opens out to a width of 18ft. Payable gold was carried down from the surface to No 11 level at a depth of 748ft. Towards the south-east the main reefs have been traced to the "beach-slide," and in a north-east direction through the old City of London, Queen of May, and May Queen leases; and in all of

these they have proved highly remunerative. In the north cross-cut from No. 11 level, two small leaders were discovered underlying slightly to the north-west. It is probable that they are "droppers" from the main reef. In the Piako shaft, which was sunk in this belt of country, two distinct reefs were cut in the upper levels, and, as in the case of the Queen of Beauty Reef, they incline towards each other and meet at No 5 level, below which they descend as one reef.

Bird-in-hand Reef.—This belt is occupied by one well-defined lode, which inclines to the north-west at an angle not far from 80°. It carried payable gold down to the 440ft. level of the Piako shaft, and was cut in the cross-cut from the No. 8 level of the Queen of Beauty shaft; but it was not opened out at that point, as the break-down in the pumping machinery in the latter mine took place while the prospecting operations were in progress.

Vanguard Reef.—This reef was first discovered in the south cross-cut from the 400ft. level from the Piako shaft. It was opened out for a distance of 100ft., and proved to be a strong, well-defined reef, maintaining an average width of 6ft. It was vertical, or dipped south-east at very high angles. The quartz was generally hard and compact, and always highly charged with metallic sulphides, principally pyrites. The 700 loads of quartz which were crushed from it yielded at the rate of about 5dwt. by the old battery-process. The tailings were treated in pans by Messrs. Brown, of Tararu, and yielded an additional 6dwt. or 8dwt. per load. The slimes were then stacked and allowed to oxidize, and were subsequently treated for a further profit. This fine reef was also cut in the cross-cut from the Queen of Beauty No. 8 level, where it opened out to 12ft. thick; and also from the cross-cut from the bottom of the Bird-in-Hand No. 1 shaft, where it was 2ft. thick.

Reefs on Foot-wall of Moanataiari Fault.

Sylvia Reef.—This is the main reef in the Tararu Creek district. It traverses the Norfolk, City of Dunedin, and Sylvia leases. It dips northwest at steep angles, seldom under 60°, and varies in width from 1ft. to 10ft. The quartz is often of a loose, sugary, or friable nature, and in the upper levels is often stained black from the presence of an abundance of manganese oxides. In the Sylvia and Norfolk Mines it contains nests and shoots of argentiferous galena, often associated with a large proportion of copper and iron pyrites and zinc-blende. In the oxidized country the gold is of fine quality, being generally worth over 60s. per ounce, and sometimes as high as 70s. A strong reef containing similar metallic sulphides is found in the No Surrender lease, near the mouth of Tararu Creek, and I think it may turn out to be the southern extension of the Sylvia Reef.

In the Sylvia Mine, the reef was worked in a south-east direction until it was cut off by a fault or "slide," beyond which it was never recovered in the Sylvia ground. I have no doubt that the search, properly conducted and directed, would soon result in its recovery. The north-east extension of this valuable reef, on the opposite side of the Ohio Stream, has received but little attention, and I have been unable to discover any sufficient reason for this neglect. The reef can be distinctly seen crossing the creek, its outcrop striking directly for the "blow" of brown hæmatite, which is situated about half a mile above the mine. I think there is every probability that this ironstone *gossan* marks the site of a rich shoot of copper pyrites and galena. The reef contains gold and silver associated with galena, blende, and pyrites at the place where it crosses the Ohio, and I am confident this end of the lode deserves a thorough exploration.

Dixons's Reef.—This reef is situated on the watershed between Tinker's Gully and the Moanataiari. It possesses the usual north-east course of the Thames main lodes, and dips to the south-east at an angle of 75° or 80°. Its course carries it southward, towards Shellback Creek, where it ends in threads of clay, in the hard, non-auriferous breccias. It has been worked since 1869, and has yielded a large quantity of gold. When poor it is very poor, and when rich, very rich; but the ore so far won from it would probably average not far from three ounces to the load. It has been stoped from the 75ft.-level, below the Whau level, up to the surface—a vertical distance of 400ft. Its width has varied from 2ft. to 5ft. The quartz is always highly mineralised with a variety of iron pyrites, very liable to decomposition. The result is the formation of the black protosulphide, and the soluble sulphate, which have rendered the extraction of gold a most difficult operation. A high rate of extraction, with such a refractory ore, can hardly be expected with the gold-saving appliances at present in use at the Thames. Besides pyrites, this reef also contains stibnite, pyrargyrite, telluride of gold and silver, and native silver.

Sons of Freedom Reef.—This reef unites with Dixon's Reef on the ridge at the source of the Moanataiari, at an altitude of 1,200ft. above the sea. From that point they gradually diverge in a southerly direction, Dixon's Reef running towards Wiseman's Gully, and the Sons of Freedom towards the Shotover. The latter is a very large reef, varying from 2ft. to 14ft. in thickness. It dips to the north-west at an angle of about 75°. It has been worked with payable results for a vertical depth of 500ft. from the surface-outcrop. At the 700ft.-level it was a strong body of stone, but was not payable, the yield varying from 3dwt. to 5dwt. per load, which did not prove remunerative on account of the heavy charges for cartage and treatment. There are tens of thousands of tons of ore in this reef which could be profitably worked if proper facilities existed for its transit and the subsequent extraction of the precious metals.

Reuben Parr Reef.—This well-known reef follows a north-east course, and dips north-west at angles varying from 75° to 85°. In places it closely approximates the vertical position. It traverses the Calliope, Orlando, and Moanataiari leases, and ends in clay strings in the hard andesite country lying against the fault. It has proved very rich in places, but the main body of the ore is low-grade. Its steep dip causes it to meet the flat-lying Golden Age Reef at the Point Russell 200ft.-level. There are still vast quantities of low-grade ore to be won from this lode.

Golden Age Reef.—This reef runs parallel with the Reuben Parr, from which it is separated by a belt of hard hornblende-andesite. It varies from 3ft. to 15ft. in width, but in several places it expands to 30ft. It dips north-west at a very low angle, rarely over 45°. It crops out on the top of Messenger's Hill, at a point overlooking the Moanataiari Fault, where it has been worked as an

open quarry. Thence it trends along the summit about 20 chains, and then gradually descends the eastern slope towards the Waiotahi, which it crosses in the Fame and Fortune lease. In this ground it joins or intersects the big Waiotahi Reef, and together they are supposed to follow the course of the stream to Punga Flat. But the exact relation which the Waiotahi Reef bears to the Golden Age Reef has not yet been definitely decided.

The Golden Age is probably the northern continuation of the Caledonia No. 1 Reef. It possesses the same underlie, and its quartz and mineral contents are similar; it also abuts against the Great Fault at the point where the continuation of the Caledonia No. 1 would be looked for. It was cut in the cross-cut from the end of the Moanataiari tunnel, but did not prove payable; but in all the shallower workings it has yielded splendid returns. The numerous hanging-wall leaders which it receives have also yielded large quantities of rich stone. Many thousands of feet of this large reef are still standing intact, and, although the most of it is low-grade, it should still yield occasional rich bonanzas.

Nana Reef.—This reef traverses the bottom of Collarbone Gully, and has been well exposed in the workings of the St. Hippo Mine. Throughout its known course it maintains a great width, averaging some 10ft. or 12ft. It contains rich patches at the intersections of the small cross-veins, which usually possess a steeper underlie than the main reef itself. It follows for a considerable distance the course of the Collarbone Fault, and this has rendered the timbering of the low-level drive a heavy and costly work, the more so as the reef and fault dip in the same direction.

Adelaide Reef.—This well-known reef traverses the Adelaide and Lone-Hand mining leases. It is situated on the lower steep slopes of Una Hill, and runs almost parallel with the Karaka at the lower end of the gorge. It varies from 1ft. to 2ft. in thickness, and has yielded many large returns of gold. Near the Lone-Hand ground it joins the Onehunga or Moa Reef, which runs across its course. The Onehunga Reef is a large and well-defined lode, varying from 2ft. to 4ft. in thickness. It has been worked with very payable results. Its course is about the same as that of the Hague-Smith Reef, of which it is possibly a northern branch.

Duke's Reefs.—There are three main reefs in this mining lease: known as Duke's Reef, a strong, well-defined lode, averaging about 4ft. thick; Dayspring Reef, from 6in. to 18in. thick; and Loyalty Reef, from 1ft. to 3ft. thick. All these reefs have yielded highly payable ore down to No. 3 level, situated about 400ft. above sea-level. They all underlie slightly to the south-east.

Occidental Reef.—This reef is small, but well-defined. It is generally vertical, or underlies slightly to the south-east. It has proved very rich at the intersections of "flinties."

Magnolia Reef.—This is the largest lode on the west side of Una Hill. It maintains an average thickness of not less than 3ft.; but in places it opens out to 18ft. or 20ft. The great mass of the quartz is low-grade.

Hague-Smith Reef.—This large reef pursues a northerly course from the mouth of Te Papa Gully to the saddle, and thence into Karaka Creek fall, on the course of the Onehunga Reef. It is a very large body of stone, averaging some 12ft. thick, and dips to the west at a high angle. Its quartz is generally hard, crystallized, and cavernous, and near the surface stained black or brown with iron and manganese oxides. Below water-level it is highly charged with iron pyrites. It is low-grade, but, so far as I can ascertain, it never falls below 4dwt. of gold per load. So far, very little work has been attempted on this valuable reef, and I am sure there is a prosperous future in store for it when it is systematically developed. It is joined in its course by a number of strong reefs, already described, which traverse the southern portion of the Una Hill in a north-east direction. Most of these have been stoped to the surface with highly payable results.

Jupiter Reef.—This is the champion lode of this end of the field. It joins or crosses the Hague-Smith at the mouth of Te Papa Gully, and thence strikes north-eastward along the north side of Hape Creek, at a distance of about 15 chains from the stream. It traverses the present Consols, Jupiter, Souvenir, and El Dorado mining-leases, and thence continues its course towards the northern sources of the creek. It has a distinct underlie to the south-east. Its average thickness is about 15ft., but in places it opens out to 30ft. or 40ft. It receives many small leaders and "droppers," many of which have proved very rich, but the main body of the reef is low-grade. This large reef possesses many advantages for successful working, and will doubtless yield payable returns in many places.

Summary of Facts relating to Reefs.

Summarising the foregoing facts, we find that the Thames Goldfield is traversed by a large number of distinct reef-systems, which run parallel with each other, and pursue a general north-east course, the only marked exception to this rule being the Hague-Smith Reef, which follows a northerly course, thus passing obliquely across the ends of the Una Hill Reefs. These reef-systems contain one, and sometimes two, main or principal lodes, and often a number of smaller subsidiary branching-reefs or leaders.

In the northern portion of the field, including that part lying between the Kuranui and the Moanataiari, the underlie of the reefs is towards the north-west, at angles ranging from 65° to the vertical position. The only exception to this are Barry's Reef, on the north side of the Kuranui, and its probable continuation, Dixon's Reef, both of which dip to the south-east at very high angles.

In the central portion of the field, lying between the Moanataiari and the Waiotahi, the main lodes underlie to the north-west at low angles, varying from 40° to 45°. Passing south of the Waiotahi, the dip of the reefs begins to steepen, and at the Queen of Beauty they dip north-west and south-east, at angles only a few degrees from the vertical. In the southern portion of the field the underlie of the principal reefs is towards the south-east, at very high angles, the only notable exception to this being the Hague-Smith Reef, which dips to the westward at an angle of about 65°.

The main lodes on the north side of the Moanataiari Creek do not live down to great depths, or, if they live, they do not preserve their gold-bearing character. In the more southern part of the field many of the main lodes have already been proved to persist through a vertical distance of

1,000ft., and, in the case of the large Golden Age and Waiotahi Reefs, not less than 1,500ft. In linear or longitudinal extension, the main lodes have been traced throughout the whole length of the field.

In that portion of the goldfield known as Block 27, situated on the seaward side of the Great Fault, the behaviour of the reef is unknown; but, in the corresponding part in Una Hill, on the foot-wall side of the fault, the reefs have been proved to be payable to a depth of 500ft. below the outcrop.

The steep reefs in the northern and southern divisions are strong, well-defined lodes, but they do not generally possess the great thickness of the flat-lying lodes in the central division. The experience of the past, however, has proved that the ore in the steep lodes is richer and more uniform in value than that forming the body of the large flat lodes.

All the lodes, both flat and steep, contain occasional patches or bonanzas of gold, often of phenomenal richness. They all receive leaders, or "droppers," in both walls, and these, as well as the places of intersection with the main lodes, have yielded many thousands of pounds in weight of specimen stone. The occurrence of "specimen stone" is one of the peculiar characteristics of the Thames and Coromandel Goldfields. In every mine the quartz showing coarse heavy gold is picked or selected, and specially treated at the periodical crushing or "clean-up."

The great mass of the quartz in the large lodes is low-grade. Large trial crushings have been made from them all, with the result that they have yielded, by the old battery process, from 2dwt. to 10dwt. of gold per load of about 32cwt.; and, judged by the experiments which I made at the large batteries last year, these results would represent an original value ranging from 8s. to 40s. per ton. The present batteries date from the early days of the field, and are not adapted for the successful treatment of such low-grade ore.

The Source of the Gold.

This is a question concerning which it is impossible to arrive at a final conclusion, on account of the scarcity of reliable data and the unique character of the rocks. In the case of stratified rocks of marine origin the solution would be easier.

Sonstadt was the first to show that every ton of sea-water contains a grain of gold, and this has since been verified by independent observers, and is now accepted as a scientific fact. When sediments accumulate on the floor of the sea, they must necessarily entangle a certain proportion of sea-water. When consolidation of the sediments takes place, the entangled fixed salts must remain behind in the rock thus formed. When such a marine rock becomes fissured and broken by igneous intrusions, and subjected to the leaching action of thermal waters with the subsequent formation of gold-bearing reefs, it is not difficult or improbable to conceive that the country rock was the immediate source of the gold.

With the Thames rocks the conditions were altogether different. As we have seen, they are of volcanic origin, and consist of decomposed andesites, called propylite, and solid andesite lavas associated with fine consolidated tuffs or ash-beds, passing imperceptibly into coarse breecias. The propylites are the gold-bearing rocks, while the tuffs and breccias, the only rocks present which are of a fragmentary character, have been shown to be singularly destitute of gold-bearing veins or lodes. It is therefore evident that we must look for some other source for the gold than that indicated in the case of marine stratified rocks. Some authorities contend that the pyrites in the propylites is the source of the gold; but I cannot agree with this, as both the gold and pyrites frequently occur in the most intimate connection, and must therefore have a common origin. Besides, it is a noteworthy fact, that the pyrites disseminated in the country rock is always as fresh as that found in the reefs. The researches of Professor Hutton have shown that the propylites are composed almost entirely of secondary products. There can then be little doubt that the pyrites also is a secondary product, as it most probably is in all cases, whether found in rocks or reefs. It is therefore quite obvious that any inquiry which goes no further than an examination of the propylites must always give results both inconclusive and misleading, since, although the presence of gold may be proved in them, it would be impossible to determine whether it were an original or secondary product.

In America, Mr. Becker made a large number of elaborate experiments in order to trace the source of the gold and silver of the Comstock Lode. He found both gold and silver in the propylites which bound the lode, existing in the same proportions as in the lode. He also made the most important discovery that the hard, fresh, undecomposed rock contained twice as much gold and silver as the decomposed rocks. His further researches showed that most of the precious metals were contained in the pyroxenes. In view of the similarity of our gold-bearing rocks, I agree with Professor Hutton that the pyroxenes of the andesites here were probably the source of the gold and silver, and that these found their way into the reefs by a process of lateral segregation. At no distant date, I hope to be able to undertake experiments to definitely determine these points.

Shoots of Gold.

In the Thames lodes, the rich places or "shoots" most frequently occur in the main lode along the points, or line of intersection of a cross-vein or a "flinty." The cross-veins vary from a mere thread to a few inches in thickness, and are often very rich. They are mostly found in the propylites. In the Cambria and Waiotahi mines they are very numerous, and often black- coloured from the presence of the ferrous sulphide. The "flinties" generally traverse the harder andesites, and, although they do not themselves contain gold, as do the cross-veins, they frequently "make" a rich shoot at the line of intersection with the main reef. These small cross-courses of flinty quartz are mostly met with in the Karaka and Una Hill areas, and are always regarded with much favour by the miners. The characteristics of many of the celebrated shoots of gold found in the Caledonia, Shotover, Waiotahi, and other reefs, are recorded in Mr. Cox's valuable report on the Thames goldfield published in the Geological Reports for 1882.

Most favourable Country.

The experience of the past twenty-seven years has proved beyond all doubt that the nature of the country exercises a powerful influence on the gold-bearing character of the reefs. The rocks that have yielded the largest quantity of gold are the soft or moderately hard yellowish grey propylites, the "kindly sandstone" of the miners, and next to those the more solid andesites. In the latter the reefs are generally smaller than in the soft country; and it is found that when a reef leaves the propylites and passes into the hard andesites, it invariably becomes smaller, or thins out to a mere parting or "clay head." The reefs in the hard country have not proved so remunerative as those in the "kindly sandstone," and, I think, this is due not so much to their less richness as to their small size and greater cost of working them.

The coarser tuffs and breccias, which generally decompose to a soft red or green mottled rock, are nearly always sterile, and, indeed, contain but few quartz-veins, and those, generally, of a chalcedonic character.

It is difficult to formulate a theory that will satisfactorily explain all the facts relating to the distribution of the rich parts; but a long personal study of the reefs and their peculiarities, aided by the valuable observations of Professor Hutton and Mr. Cox at the Thames, and Mr. Becker, at the Comstock Lode, has lead me to the following conclusions: First, that the main lodes were the primary channels or fissures, at one time filled with slowly circulating waters containing gold and silver, and probably base metals, in solution; and, second, that the cross-veins were secondary fissures filled with waters containing the metallic salts necessary for the electro-chemical deposition of the noble metals. This would explain the occurrence of the rich shoots at the places where the cross-veins meet the main lodes, and render it easy to understand how the precipitated gold would be distributed as "shoots," sometimes broad and narrow, steep and flat, according to the strength and direction of the circulating currents. It may be that, in some cases, the converse would be nearer the truth: that the solutions of the precious metals were carried by the cross-veins, but this would not apply to the "flinties," which are always barren.

Moissenet, in his work on the "Lodes of Cornwall," formulated the following laws with respect to the distribution and characteristics of the rich parts of the metalliferous lodes in that ancient mining region: (1) That the rich parts are those most nearly vertical; (2) that the rich parts are enclosed in rocks of moderate hardness; (3) that the rich parts dip in the same direction as the country.

The last two have a general application here, but the first will not satisfy the conditions and facts prevailing in the different parts of the goldfield. In the Kuranui, Queen of Beauty, Karaka and Una Hill, the reefs seem to have been richest where they approached the vertical position; but, on the other hand, the great bonanza of the Caledonia, the largest and richest shoot of gold known in the history of gold-mining, occurred in a reef so flat that the mullock would hardly run in the passes, and even the shoot itself was very flat.

The law that the rich parts are those most nearly vertical must fail as a useful generalisation, unless we are prepared to believe that all lodes now occupy the same relative position to the horizon they did when filled with mineral matter. In the case of a country like New Zealand, continually subject to the disturbing influence of plutonic forces, and where rocks of the youngest date are found inclined at high angles, it is improbable that lodes formed even in steep fissures would occupy that position for any great length of time. This would apply with the greatest force in the case of the older rocks, which have necessarily been subjected to all the earth-movements which have disturbed and tilted the younger rock-masses. A lode may occupy a vertical position in one geological age, and a nearly horizontal position in another; and, for this reason, Moissenet's law can never obtain a general world-wide application. Each lode will be found to possess certain peculiarities and distinctive features of its own; and it is desirable that the mine-manager should thoroughly understand these, to make his mine pay advantageously.

Form and Value of the Gold.

The gold occurs principally as fine irregular grains, threads, and thin plates or scales; but one or all of these may be found in the same hand-specimen. I have not infrequently met with crystallized gold, occurring mostly as cubes or octohedrons arranged in short wiry strings; but regular, well-shaped crystals are rare.

The gold is alloyed with silver to the extent of 30 or 40 per cent., the value ranging from £2 8s to £2 16s. per ounce. The value varies in the different reefs, and even in the same lode the value will vary several shillings per ounce within the height of a stope. The gold from the Kuranui Hill is usually of less value than that from other parts of the field, while that from the Sylvia Reef system in Tararu Creek is much higher, ranging from £3 to £3 12s. The gold obtained from Hunt's Shotover Claim was valued at £2 9s. 8d. per ounce; from Barry's Reef, £2 10s.; from Tookey's Claim, £2 15s.; and from the Golden Crown, £2 15s. 10d. The present average fineness of Thames gold is about 680.

Associates of the Gold.

The experience of mining in all parts of the world has shown that certain minerals are constantly associated in the same lode. This paragenesis has its application in all classes of metal-mining. The minerals associated with the gold at the Thames are mostly very characteristic, and are generally spoken of by the miners as "favourable minerals." The most common and abundant is iron pyrites. After this, in the order of their common occurrence, come copper pyrites, zinc-blende, stibnite, and ruby-silver.

In the Tararu system of reefs the gold is always found with galena, manganese oxides, and calcite, besides blende, iron and copper pyrites. The former is seldom, or indeed never, seen in the Thames area, while the calcite and manganese oxides are not at all common. In the rich patches in Una Hill pearl-spar is always found with the gold. The distinctive and most favourable minerals

in the different parts of the goldfield are as follows: In Una Hill and Karaka, pearl-spar; in the central and northern divisions, ruby-silver, copper pyrites, and stibnite; and in Tararu Creek, galena, resinous-coloured blende, manganese oxides, and copper pyrites. In the Occidental Mine, in Una Hill, resinous-coloured blende was a constant associate of the gold in the rich parts.

Future Prospects of the Goldfield.

During the twenty-seven years that have elapsed since the opening of this field, the working of the mines has been principally conducted by private enterprise, or by companies with local interests. The richness of the lodes and leaders permitted the operations to be conducted, in most cases, with a small working capital, and in this way the more readily-accessible gold-bearing veins have become gradually exhausted. The production of gold, up to the end of last year, was valued at over £5,500,000—a yield unsurpassed by any other goldfield of the same area.

Besides yielding so large a treasure, the mining operations of the past have added much valuable information respecting the distribution and extent of the gold-bearing reefs and country, which will be of great value in the subsequent development of the field. There is a widespread, but erroneous, impression, that the Thames, as a goldfield, is rapidly approaching its end. The fact is, that it is simply nearing the end of the first stage of its existence. It is an undoubted fact that the main reefs of the Thames are more numerous, and of greater persistency in size and extent, than those of any other goldfield in New Zealand, and their development promises a brighter and more permanent prosperity for the future than that experienced in the past. The period intervening between the end of the old and the beginning of the new condition is certain to be a period of acute depression and stagnation, and the longer the interval the greater the depression will be.

After mature consideration, I have arrived at the conclusion that the future extension of the field may be effected from three different directions. First, there is the systematic development of the large low-grade reefs which exist in the Moanataiari, Waiotahi, Una Hill, and Hape areas. Among these should be specially mentioned the Sons of Freedom, Reuben Parr, Golden Age, Waiotahi, Hague-Smith, and Jupiter Reefs, in the Thames proper,—all large, persistent, well-defined, gold-bearing lodes. I am confident that our future wealth lies in our low-grade ores; and have no hesitation in saying that the undeveloped wealth contained in the millions of tons of ore in these reefs forms one of the most valuable and reliable assets of the Hauraki Goldfields.

Most of the lodes enumerated above could be worked "water-free" for many years, and only require cheap transit for the ore, and efficient battery treatment, to be made to yield steady returns. A work of great urgency is the extension of the Moanataiari Tunnel, which would then be an underground road and adit of great public utility, and enable large blocks of ore, at present left standing, to be worked with advantage and profit. Examples of what may be effected by cheap milling, together with a high rate of extraction, is afforded by the leading mines at Waihi and Karangahake, where low-grade ore is made to yield steady dividends. It was proved conclusively, some years ago, that the same ore, when treated by the ordinary wet-battery process, would not pay half the working expenses.

In the second place, there is the development of the large gold-bearing reefs in the northern extension of the Thames auriferous belt, in the upper valleys of the Tararu and Puru Streams. Some of these reefs attain a thickness of 40ft., and they are traceable on the surface for thousands of yards. They are enclosed in the most favourable class of propylite, and, wherever they have been tested, they contain gold. In the early days of the goldfield they attracted a good deal of attention. Several batteries were erected in their vicinity, and, even with the crude appliances then in use, they were made to yield thousands of ounces of the precious metal. From then till now they have lain neglected and almost forgotten. At the present time, however, two small four-stamper batteries are being erected to further test them: one at Lowrie's Reef, in the Tararu watershed, and the other in Puru Creek, above the Forks, to crush stone from the splendid reefs which traverse the wooded ranges forming the watershed between the Puru and the Tararu Streams. The erection of these small batteries by private enterprise in such inaccessible places can only be accomplished by much self-sacrifice and a brave determination to overcome all obstacles. It is sincerely to be hoped that these pioneers will reap an ample reward for their efforts; but, whatever their results may be, I am convinced that there is a bright future in store for these districts, whenever the capital is available for their development on a large scale. The reefs are mostly low-grade, and the bulk of the gold is so fine that it will require the best appliances and skill for its profitable extraction, and these can only be obtained by the expenditure of money.

In the third place, there is the working of the deep levels on the Thames foreshore. This may be considered under two distinct phases—namely, the exploration and working of the deep ground lying below the existing levels; and the development of the large area of virgin ground lying under Block 27.

The working of the deep ground, below the present levels, could be most easily effected by deepening one of the existing shafts on the foreshore and at once opening out new levels on the best-known gold-bearing reefs. If these proved to be payable, still lower levels could be constructed, and this course could be continued so long as the results warranted the additional expenditure.

The systems of reefs which, from the splendid returns obtained from them in the upper levels, especially deserve to be thoroughly tested in this manner are the Saxon, Queen of Beauty, and Vanguard. These contain many strong well-defined lodes, which have been proved to exist in the lowest workings so far undertaken upon them. From the necessity which exists of erecting suitable pumping and winding machinery, this will be a costly, although a thoroughly legitimate, mining undertaking.

Of the reefs in Block 27, nothing of positive character is known, as the gold-bearing formation in that area is obscured by Pleistocene high-level terrace gravels and clays, which in places attain a thickness of 300ft. It is, however, perfectly certain that the numerous strong reefs which traverse Una Hill, on the foot-wall of the great fault, also traverse this faulted hanging-wall portion. Experience in the northern and middle divisions has shown that the rocks on the seaward side of the great fault are more decomposed than those on the upland side; also that the contained reefs are as rich, or richer, than those in the harder country. Therefore I think it is only fair to assume that this will be the case with the Una Hill reefs and rocks when found under the Block. But this scheme, like the former, can only be accomplished by the aid of capital. The whole of the workings will be situated below water-level, and this will necessitate the erection of pumping and winding machinery capable of reaching at least a depth of 1,200ft. or 1,500ft. This area, like the known parts of the field, is no doubt traversed by wide bands or belts of propylite or "kindly country," separated by bars or cores of hard tuff, breccia, or andesite. It seems to me this is a case where the diamond-drill might be used with much benefit, in order to supply information as to the exact nature of the country below, before selecting a site for the pumping and winding-shaft. If a site were selected haphazard, and a vertical or highly-inclined bar of andesite encountered, the cost of sinking and construction would be greatly increased, and, even when completed, the additional cost of cross-cutting the hard country at the different levels would tend to endanger the success of the whole undertaking.

From a long personal acquaintance with the characters and peculiarities of the gold-bearing country and the reefs of the Thames Goldfield, I am convinced that, when her main lodes and low-levels are fully developed, she will enter on a second lease of life, more prosperous, although, perhaps, less exciting, and infinitely more enduring than the first. In Hungary, reefs of a similar character, and in the same class of country, have been profitably worked for over eight hundred years; and this fact, I think, augurs well for the future prospects of this goldfield.

MIDDLE ISLAND.

Marlborough District.

Waikakaho.

The Ravenscliff Mining Company have expended a large sum of money in opening-out the quartz lodes in this locality without being recouped in any way for their outlay. This company purchased the properties from H. F. Logan and party, and erected a 10-head crushing-battery, having an aërial tramway three miles long to connect the mine with the battery. There is a peculiarity about this tramway that is not to be found in any other in the colony; it is not constructed on a straight line, the same as the other aërial tramways, but has a bend in it near the centre of about 115°.

The representative of the company who took charge of the operations at the crushing-battery could not get a yield of more than about 4dwt. of gold to the ton, notwithstanding that gold could be freely seen in the stone; so that, after working until the capital was exhausted, the company suspended operations. At this time there was in the hoppers at the mine a few tons of quartz, which was considered would not pay the expense of sending down and crushing. It was thought at the time that the whole of the gold was not being saved at the crushing-battery, and samples were sent elsewhere to be tested, which gave excellent results. After suspending operations the stone remaining in the hoppers was sent away to Sydney and London to be tested.

Sent to Sydney:—
First parcel, 6 tons, yielded 8dwt. 8gr. of gold to the ton.
Second parcel, 6 tons, yielded 15dwt. of gold to the ton.
Sent to London:—
First parcel, 10cwt., yielded 16dwt. 6gr. of gold to the ton.
Second parcel, 10cwt., yielded 14dwt. 19gr. of gold to the ton.
Third parcel, 10cwt., yielded 10dwt. 12·7gr. of gold to the ton.

Taking the average of the five tests, the yield of gold was equal to 12dwt. 23·5gr. per ton, representing a value of about £2 12s. 8d. per ton. The ordinary battery process, however, would not extract the percentage of gold out of the ore, as was done in London, unless a different method of treatment was adopted. The different percentages of gold extracted being 92 per cent., 93 per cent., and 86 per cent., respectively.

It seems that, when the property was purchased from H. F. Logan and others, there was an agreement to the effect that the Ravenscliff Company, if necessity arose, was to apply for debentures to the extent of £500, and, on this being done, H. F. Logan, on notification of receipt of such debenture-moneys, agreed to transfer to each subscriber fully paid-up shares of equal nominal value to the amount of his debentures. Messrs. Logan and Duncan have placed 3,000 fully paid-up shares at the disposal of the London Board of Directors to assist them in raising sufficient money on debentures to give the company capital to commence operations again, and to add a plant that will save a fair percentage of the gold. There is a prospect, therefore, of the company giving the Waikakaho reefs another trial.

Wakamarina.

Although there have been very rich deposits of gold in the bed of the Wakamarina, and also in Deep Creek and Dead-horse Creek, which are two of the tributaries of the river, very little gold has been obtained in the terraces. A large quartz-reef was discovered on the side of the range facing Deep Creek, and a little gold found in the stone, but, so far, it has not proved to be of a payable character for working. A company was formed to work this reef, under the title of the Golden Bar Company, but, after doing a good deal of prospecting, they have suspended operations. On the discovery of the Golden Bar Reef, a number of claims were taken up on the supposed line of reef, between Dead-horse Creek and Deep Creek, and short adits driven into the face of the range, without the discovery of anything considered worth working.

A few months ago Mr. James Wilkie and party went into one of these old adits and found a quartz lode which the adit had cut through, but, apparently, the party who constructed the adit did not, at that time, consider the lode payable for working. Mr. Wilkie's party prospected this lode, which is about 8ft. in thickness, having the foot- and hanging-walls extremely well defined, and the whole of the lode is composed of very fair-looking stone. The centre portion of it is of a white chalcedonic character, but when broken up it is found to be vesicular, the cavities containing oxidised pyrites, and when crushed in a mortar fine gold can be obtained. The stone on the hanging and foot-wall side of the lode, especially on the foot-wall side, has a better appearance as gold-bearing stone. On the foot-wall side there is a percentage of scheelite in the lode. Judging from the prospects shown me by Mr. Wilkie from small pieces of stone crushed in a mortar, this lode should pay for working. At the same time it is not likely to give large returns, but by a systematic mode of working and careful management should be a fair property.

The present workings are about 604ft. above the level of the flat, where it is intended to erect an Otis crushing-mill. The stone is to be brought down by means of two chutes, lined in the bottom with an iron plate. One of these will lead from the mouth of the adit for a certain distance down the range, and it is proposed to have a tramway for a short distance to connect with the second chute. The distance from the adit to the flat is between 50 and 60 chains. It is proposed to bring in a water-race from Dead-horse Creek, and use water-power for crushing. It is questionable if a large percentage of the gold will be saved by the ordinary battery process, as the gold is very fine, but it is specially adapted for treatment by the Cassel process. When once the crushing-machine is erected here it may be an incentive for other parties to prospect the lodes in the locality, as there will then be an opportunity of getting the stone tested.

This part of the Wakamarina district is well worthy of being prospected for auriferous lodes. The gold that has been found in the beds of the creeks already referred to is so intermixed with quartz that it clearly points out that both the Deep and Dead-horse Creeks have cut through rich auriferous shots of gold in lodes; and there are sufficient indications, from what has been discovered by Mr. Wilkie and the Golden Bar Company, to prove that rich stone exists somewhere in the range to the north side of the Wakamarina River. Very little gold was found in the alluvial drift in these creek-beds above the line of reefs. The character of the stone in the lode discovered by Mr. Wilkie and party is totally different from the Golden Bar lode, the stone in the latter being greatly laminated and very hard. Nevertheless, it is almost certain that a rich shot of gold will yet be found in the Golden Bar lode. The district has never been prospected much in either alluvial or quartz; but, of the two classes of gold-working in this particular locality of the Wakamarina, there is a probability of a much greater discovery being made by prospecting for quartz lodes than there is in prospecting the alluvial drifts. The gold found in the bed of the Wakamarina River is simply a concentrate of the large quantity of material which the water has washed away, leaving the denser particles in its bed, on the same principle as gold is collected at the present day in a ground-sluice. The river resembles nothing else but a gigantic sluice-box, re-assorting the material of the slips from the sides of the range, which are continually falling into its bed. The schist and slate soon gets broken up by the action of the water and the atmosphere, and the light material is carried away by the stream, leaving behind what gold there was in the material.

Collingwood District.

The only quartz-working of any note in this district is that of the Johnston's United Company, who hold a quartz claim at the head of Bedstead Gully. The lode varies considerably; sometimes it is lying almost horizontal, or with a slight inclination resembling a coal-seam, and occasionally it dips rapidly for a short distance, and, so far, rich auriferous stone has been found in close proximity to where these rapid dips occur. With the lode lying so flat, it becomes difficult to fill up the ground so as to prevent the roof caving in. The stone is generally of low-grade where the lode is found in a slightly inclined or horizontal position, and the most of the payable portion of the lode has been taken out on the upper levels. So that, before large operations can be again carried on, either another level will have to be constructed, or a shaft sunk, to work the lode to a much greater depth than at present. During the past year 4,561 tons of quartz was crushed, which yielded 914oz. of gold, equal to an average yield of a trifle over 4dwt. of gold per ton.

There are other quartz lodes in the district from which rich yields have been obtained, but there does not seem to be any disposition on the part of the miners in the locality to carry on prospecting operations in quartz-reefs to any extent. Some years gone by, good stone was obtained at the Red Hill Mine in small veins, and the property was purchased by an English company for £100,000. The ground has been lying idle ever since, and is looked on by the miners of the district as practically valueless. Nevertheless, the ground is well worth prospecting.

Reefton District.

Quartz-mining in the Reefton District is at a lower ebb than ever it has been since the commencement of the field. There is very little outside capital coming into the place, and the claims not turning out according to expectations is casting a gloom over those who have their permanent abodes in the place and are depending for their livelihood on the success of the mines. If something is not done to carry on prospecting in this district a large portion of the mining population will have to seek "fresh fields and pastures new." Men will have to sacrifice what little property they have acquired, and, in many instances, perhaps, spend what little money they possess before they get employment elsewhere. It may be said that this is too gloomy a view to take of the aspect of affairs; but, were any one to visit Reefton and obtain possession of actual facts in connection with the workings in the mines, they will come away imbued with the same sentiments. The district is a large one over which payable quartz-lodes have been discovered; but the same system prevails here as in many other places, all the profits in working the mines are divided amongst the shareholders, and no fund put by to prospect and open up the ground and thus postpone the day of adversity.

The Keep-it-Dark Company and Welcome Company have both paid away large sums in dividends to the shareholders: the former paid about £108,033, and the latter £110,250; if only 5 per cent. of the actual profits had been placed to a reserve fund, the former company would now have about £5,401 and the latter £5,512 with which to further prospect the ground. This may not appear on the face of it to be advisable, as some may say that the shareholders are entitled to the use of the money, and when moneys are required to further develop the mine calls can be made. But the evil of this is that, while a mine is paying large dividends, the price of the shares is generally pretty high, and those in a position to obtain the latest information in regard to the workings of the mine have a considerable advantage over the other shareholders, as they know when to put their shares in the market; and people buying them do so with the idea that the mine has been paying a certain amount in dividends yearly for a considerable time, and they expect that the same thing will take place in the future; whereas the person buying the shares may have paid a high price for them, and only got a dividend or, perhaps, two, before the whole of the dividend-paying stone is worked out. The result of this is that a new class of shareholders come in, who have spent the most of their capital on the purchase of shares, and when the evil day comes they are not in a position to pay calls.

It is a question whether the Government of the colony, or nation, where minerals are found should not make it compulsory for companies to create a reserve fund out of a percentage of the profits in working a mine. The minerals are the property of the Crown—at least, so long as they are in Crown lands; and, if the Government intrust men to develop that property to the best advantage, it should have control over the manner in which mines are worked and operations conducted. In many instances, mining is carried on in such a manner that the future development of the workings is hampered to such an extent that large additional expense must be incurred before any fresh works can be undertaken. Indeed, it could even be put stronger than this, seing that, in some instances, the workings have been carried on in such a manner as to destroy any reasonable chance of the mine being again taken up and worked advantageously.

The two companies already mentioned—namely, the Keep-it-Dark and Welcome—are now applying to the Government for assistance to test the deep levels; and, no doubt, other companies, who have spent their capital and received nothing in dividends, may consider that they are equally entitled to assistance: but the field has now arrived at that stage when prospecting will have to be carried on if mining is to continue in the district; and the land where the quartz lodes are situated is not suitable for anything else but mining, and, were that industry to collapse, the land would be valueless, and settlers who have taken up land on the small flats near Reefton would also be ruined, as they would be deprived of a market for their produce.

The cry in the district is, "Get the deep levels prospected"; but it becomes a grave question whether there is a better prospect of getting gold by sinking, or by following the track of the lodes with the view of finding another shot of gold-bearing stone on the same line of lode that has been previously worked. It is well-known that in all lodes there are rich and barren portions, and the prospector is not to be disheartened when these barren patches are met with, so long as the walls of the lode are found well-defined, with only a little soft pug between them. This indicates the track of the lode, and should be followed, with the view of again striking or meeting with ore payable for working. No doubt there is a chance of meeting with payable ore by following the present shots down; but there is no gainsaying the fact that the lodes in New Zealand have got poorer as the depth increased: still, this is no criterion that new lodes will not be found at a greater depth, even should those which have been worked from the surface downwards completely pinch out. This took place at Bendigo, where the lodes in some of the mines completely cut out, and, after sinking through 750ft. of entirely barren ground, fresh lodes were again found, but not so rich as those nearer the surface. We cannot, however, apply the conditions in which the lodes occur at Bendigo to those at Reefton, as the formations in which they occur are entirely different. The country about Bendigo is of a far older formation than that about Reefton, and has never been subjected to so many disturbances, nor have the same dislocations taken place that are so characteristic of New Zealand. We are entering upon a stage in mining which no one can say with certainty whether success will attend the undertaking or not. Men investing their money must be prepared to lose it if the venture does not prove a payable one. The whole question is involved in obscurity, and we shall have to get further data to work on in order to frame a reasonable theory as to the genesis of mineral ores, before we can demonstrate clear ideas as to the depth at which mining operations are likely to be carried on with success in different parts of the country.

The results of the workings last year do not show so bad a position as what the mines are really in. Some of the mining companies who are now paying dividends are near the end of their tether, and there do not appear to be others in a position to take their places. So long as there are a certain number of dividend-paying mines on a field, it always holds out inducement for people to prospect their properties. This gives employment to a number of men, and presents a hopeful aspect for future workings.

The following is a return of the number of tons of quartz crushed, the yield of gold from same, and the dividends declared, for the year ending the 31st of December last, forwarded to me by Mr. Hindmarsh :—

Name of Company.	Quartz.	Gold.	Yield of Gold per ton.	Dividends.
	Tons.	Oz.	Dwt.	£
Progress	11,100	4,500	8·10	4,200
Big River	2,445	3,912	32·00	6,600
Cumberland	3,900	3,520	18·05	4,800
Globe	8,890	2,910	6·54	...
Wealth of Nations	2,595	868	6·69	...
Golden Lead	3,740	646	3·45	...
Hercules	612	414	13·53	900
Royal	415	413	19·90	...
Sir Francis Drake	1,483	294	2·61	...
Keep-it-Dark	868	277	5·23	...
Venus	309	138	8·93	...
No. 2 Keep-it-Dark	105	70	13·33	...
Specimen Hill	27	36	26·66	...
St. George	15	35	46·66	...
A1	6	34	113·33	...
Lord Edward	32	34	21·19	...
Private Companies—				
Boatman's Tailings Company ...	...	329	...	...
Energy Company	525	181	6·89	...
Fiery Cross Company	140	72	10·55	...
Totals	37,207	18,683	...	...
Alluvial—				
Purchased by Banks	...	3,979	...	...
Other sources	...	1,000	...	...
Totals	37,207	23,662	...	16,500
Total, 1872 to 1893 ...	616,092	567,685	...	543,351

Total value of gold yield since 1872, £2,222,032.

It will be seen by the foregoing statement that 37,207 tons of stone has been crushed, which yielded 18,683oz. of gold. This would represent a value of about £74,652; and of this amount £16,500 was paid in dividends. During the previous year the quantity of quartz crushed amounted to 38,561 tons, yielding 21,636oz. gold. which would represent a value of £86,544. Of this amount dividends to the value of £17,800 were paid. This shows a falling-off in the yield of gold for the year 1893 to the extent of 2,953oz.

Taking the year ended the 31st March last, there was 34,518 tons of quartz crushed, which yielded 18,413oz. gold, representing a value of £73,752 14s. 11d. Of this amount, £18,832 was paid in dividends; and during the same period calls to the extent of £14,350 were made. Comparing these returns with the previous year, ended the 31st March, the yield of gold for that year was 20,171oz., representing a value of £80,894 5s. 1d., which shows a falling-off last year to the extent of 1,758oz. gold. There is no question but that, during the last four years, the yield of gold from the mines in the Reefton District has been gradually falling off; but even the yield of gold last year was considerably more than what it was in 1885–86, when it only amounted to 14,591oz., representing a value of £56,904 18s. Therefore, notwithstanding the present depression in the Reefton District, the value of the produce last year amounted to £16,847 16s. 11d. more than it did eight years ago.

The following statement will show the comparative returns from the mines in this district for the last twelve years, ending the 31st March in each year:—

Year.	Calls made.	Dividends declared.	Number of Tons of Quartz crushed.	Yield of Gold.	Value of Gold.	Yield per Ton.
	£	£	Tons.	Oz.	£ s. d.	Oz. dwt. gr.
1882–83	61,345	32,600	18,928	19,194	74,856 12 0	1 0 7
1883–84	49,456	16,500	23,433	16,547	64,533 6 0	0 14 3
1884–85	29,333	34,100	34,349	23,997	93,588 6 0	0 13 23
1885–86	24,565	14,500	27,198	14,591	56,904 18 0	0 10 18
1886–87	21,596	33,450	23,930	21,143	83,171 15 5	0 17 14
1887–88	30,432	17,550	24,403	16,775	66,030 11 5	0 13 18
1888–89	38,919	16,688	28,564	18,663	72,720 18 0	0 13 4
1889–90	27,531	18,250	32,394	17,780	69,676 12 1	0 10 16
1890–91	20,404	27,325	39,643	23,347	91,998 8 10	0 10 19
1891–92	25,956	30,743	35,562	23,390	93,885 5 1	0 13 3
1892–93	18,800	16,900	37,693	20,171	80,894 5 1	0 10 16
1893–94	14,350	18,832	34,518	18,413	73,752 14 11	0 10 13

The following is a statement showing the different companies that have been engaged in mining in the Reefton District since it was opened, showing the amount paid in calls; dividends received; the number of tons of stone crushed; the yield of gold therefrom; and the value of the gold produced:—

QUARTR-MINING COMPANIES engaged in the REEFTON DISTRICT.

Name of Company.	Calls made.	Dividends declared.	Stone crushed.	Yield.	Value.
	£ s. d.	£ s. d.	Tons.	Oz.	£ s. d.
All Nations	400 0 0	...	...	...	...
Alston	100 0 0	...	...	...	...
Alexandra	600 0 0	...	394	168	651 0 0
Argosy	1,687 10 0	...	...	...	...
Argus	500 0 0	...	82	105	407 6 4
A1	350 0 0	9 0 0	173	34	799 4 3
Ajax	...	2,504 0 0	6,890	6,441	24,958 17 6
Anderson's Creek	...	475 0 0	6,791	5,363	20,780 12 6
Big River	3,500 0 0	14,100 0 0	4,804	6,851	27,468 3 9
Big River Extended ...	2,400 0 0	9,600 0 0	2,497	4,792	18,075 7 0
Bannockburn	450 0 0	...	...	...	...
Britannia Extended ...	104 3 4	...	...	...	...
Blue Sky	300 0 0	...	...	...	...
Britannia Quartz Company ...	416 13 4	...	...	...	...
Band of Hope	...	...	390	25	96 5 0
Boatman's Creek	...	...	138	122	472 15 0
Boatman's Tailings ...	...	...	...	440	830 0 0
Chicago	600 0 0	...	...	...	...
Cumberland	2,400 0 0	13,200 0 0	11,550	9,800	40,233 2 0
Caledonian Extended ...	651 0 0	...	...	...	...
Caledonian	...	2,250 0 0	546	2,052	7,951 10 0
Dauntless Extended ...	550 0 0	...	...	...	...
Durham	800 0 0	...	...	...	...
Dillon	700 0 0	...	...	...	...
Eureka Extended	10,195 0 0	...	...	...	...
Eureka	5,666 13 4	...	...	...	...
Eclipse	100 0 0	...	...	...	...
Empress	1,850 0 0	...	...	...	...
Exchange	2,600 0 0	...	...	...	...
Energy	...	...	4,766	2,367	9,325 11 9
Edinburgh	100 0 0	...	...	...	...
Energetic	...	21,900 0 0	59,080	30,811	119,322 7 8
Eldorado	...	...	478	653	2,530 7 6
Great Eastern	1,103 0 0	...	...	...	...
Fiery Cross	...	...	384	191	765 0 0
Fiery Cross Extended ...	4,824 10 0	9,243 0 0	8,372	7,894	31,436 3 4
Fraternal	300 0 0	...	...	...	...
Frying-pan	687 10 0	...	...	...	...
Gallant	4,200 0 0	600 0 0	2,036	659	2,623 7 8
Globe	14,775 0 0	40,000 0 0	67,363	32,949	130,618 0 0
GoldenTreasure	19,600 0 0	4,300 0 0	9,179	5,858	22,773 14 1

QUARTZ-MINING COMPANIES engaged in the REEFTON DISTRICT—*continued.*

Name of Company.	Calls made.			Dividends declared.			Stone crushed.	Yield.	Value.		
	£	s.	d.	£	s.	d.	Tons.	Oz.	£	s.	d.
General Gordon	1,500	0	0	...			...	...	...		
Golden Point	7,350	0	0	...			1,005½	333	1,295	16	10
Golconda	200	0	0	...			...	...	...		
Golden Hill	1,900	0	0	...			39	9	36	7	1
Guide	100	0	0	...			...	...	...		
Golden Lead	5,500	0	0	...			10,445	2,102	8,425	17	9
Golden Bar	400	0	0	...			...	...	...		
Golden Arch	...			...			149	139	538	12	6
Golden Ledge	...			...			1,831	552	2,039	0	0
Golden Fleece	...			...			406	167	668	0	0
Golden Fleece Extended ...	6,773	0	0	55,000	0	0	25,087	31,753	123,070	12	0
Hercules	5,000	0	0	3,200	0	0	2,480	2,029	8,041	9	8
Homeward Bound... ...	8,775	0	0	...			62	213	859	13	7
Happy Valley	3,150	0	0	...			127	29	110	19	1
Hudson	100	0	0	...			...	...	...		
Hard to Find	1,650	0	0	...			60	17	67	0	0
Hopeful Extended... ...	2,103	2	6	40,425	0	0	12,898	21,129	81,698	0	7
Heather Bell	...			...			60	10	40	0	0
Inkermann	18,105	6	8	4,000	0	0	28,492	11,968	46,272	10	7
Inglewood Extended ...	3,400	0	0	2,700	0	0	9,103	5,693	22,047	0	0
Inangahua Low-level Tunnel	5,456	0	0	...			...	...	...		
Independent	...			...			2,345	1,179	4,568	12	6
Italian Gully	...			...			879	512	1,984	0	0
Invincible	...			1,050	0	0	564	657	2,545	17	6
Imperial...	...			...			811	468	1,813	10	0
Just in Time	11,667	13	4	15,666	0	0	12,459	15,384	59,832	2	10
Keep-it-Dark	5,125	0	0	108,033	0	0	112,644	59,726	232,530	6	5
Keep-it-Dark No. 2 ...	5,800	0	0	9,200	0	0	9,088	6,175	24,572	19	6
Kapai	800	0	0	...			...	...	...		
Lord Edward	2,296	0	0	...			30	34	133	12	2
Lone Star	5,200	0	0	...			220	75	291	12	0
Londonderry	200	0	0	...			...	...	...		
Lone Hand	850	0	0	...			...	...	...		
London	250	0	0	...			...	...	...		
Lady of the Lake	...			...			10	3	11	2	6
Lankey's Creek	...			...			680	73	277	19	3
Merrijigs...	2,100	0	0	...			...	...	...		
Maori Chief	100	0	0	...			...	...	...		
Mount Morgan	150	0	0	...			...	...	...		
Multum in Parvo	150	0	0	...			...	...	...		
Mammon	...			...			15	15	60	0	0
Murray Creek	753	0	0	...			...	...	...		
New Era	250	0	0	...			...	...	...		
Nil Desperandum	11,112	3	4	287	10	0	6,858	3,393	13,165	7	7
New Britannia	437	0	0	...			...	...	...		
New Golden Point ...	1,000	0	0	...			...	...	...		
North Venus	200	0	0	...			...	...	...		
National...	1,200	0	0	...			...	...	...		
No. 2 South Larry ...	...			...			7,514	4,129	13,999	17	6
O.K.	100	0	0	...			...	...	...		
Oi Polloi...	100	0	0	...			...	...	...		
Oriental	...			...			3,360	1,190	44,603	2	6
Prince of Wales	150	0	0	...			...	...	...		
Progress	3,900	0	0	13,200	0	0	43,950	20,651	91,647	15	8
Pandora	2,400	0	0	...			699	364	2,611	3	2
Phœnix Extended... ...	700	0	0	4,533	6	0	2,190	2,918	11,272	11	10
Prima Donna	600	0	0	...			...	...	...		
Perseverance	...			...			57	19	73	12	6
Pactolus	...			1,000	0	0	108	498	1,929	15	0
Queen	50	0	0	...			...	...	...		
Reward	250	0	0	...			...	...	...		
Reform	3,090	0	0	...			704	445	2,145	15	6
Royal	1,850	0	0	232	0	0	810	722	2,910	18	10
Resolution	500	0	0	...			...	...	...		
Rise and Shine	150	0	0	...			...	...	...		
Rainy Creek Extended ...	6,739	0	0	...			1,782	209	809	0	0
Sir Francis Drake... ...	12,750	0	0	...			5,712	1,163	4,440	1	2
Scotia	4,443	10	10	3,000	0	0	594	1,284	5,062	17	6

QUARTZ-MINING COMPANIES engaged in the REEFTON DISTRICT—*continued.*

Name of Company.	Calls made.			Dividends declared.			Stone crushed.	Yield.	Value.		
	£	s.	d.	£	s.	d.	Tons.	Oz.	£	s.	d.
Specimen Hill	9,270	0	0	...			2,265	1,205	4,222	14	4
Supreme	4,882	13	4	...			417	51	170	10	0
Sir Charles Russell ...	3,700	0	0	...			28	45½	164	11	6
South Wealth of Nations ...	1,750	0	0	...			...	...	...		
South Hopeful	4,315	0	0	...			48	52	217	1	9
Stanley	100	0	0	...			...	...	...		
Success	400	0	0	...			...	...	...		
St. George	600	0	0	...			15	35	140	14	1
Southern Cross	...			...			21	43	166	12	6
Triumph	1,150	0	0	...			...	...	...		
United Devonshire ...	1,778	7	8	...			...	...	...		
Union	...			...			600	64	248	0	0
United Inglewood and North Star	...			...			1,591	821	3,181	7	6
United Band of Hope ...	...			...			160	49	187	17	6
Venus Extended	4,000	0	0	3,300	0	0	8,247	5,495	21,318	11	9
Victoria	...			...			1,617	831	3,234	17	6
Venus	700	0	0	600	0	0	2,466	1,419	5,524	2	6
Victory	...			...			1,155	905	3,506	17	6
Vulcan	...			400	0	0	919	586	2,077	0	0
Wealth of Nations Extended	6,500	0	0	...			4,077	2,007	7,883	2	0
Welcome	11,100	0	0	110,250	0	0	26,886	63,465	247,817	3	1
Walhalla Extended ...	1,437	0	0	...			238	354	1,396	5	3
Wealth of Nations ...	13,975	10	0	35,100	0	0	51,675	29,912	116,035	18	7
Welcome United	3,600	0	0	...			...	...	...		
	305,378	14	4	529,428	16	0	594,461	449,486	1,696,997	5	9

It will be seen from this that calls to the extent of £305,378 14s. 4d. have been made, while dividends amounting to £529,428 16s. have been paid, showing that, notwithstanding the money that many people have lost in mining ventures in Reefton, there was £224,050 2s. 8d. more paid in dividends than ever was called up by mining companies. There is no doubt many of the ventures proved unsuccessful; but, taking the quartz-mining industry as a whole in this district, it gave fair returns for the capital actually called up.

In remarking on the progress of the quartz-mining industry at Reefton, it is only necessary to refer to some of the principal claims, as each company is dealt with seriatim in the Warden's reports.

Welcome Company.—The amalgamation of the Welcome, Homeward Bound, and Eureka Mines resulted in the formation of a new company, which is called The New Welcome Company. The operations are being carried on from the Eureka inclined adit, which is about 1,800ft. in length, having a vertical dip in this distance of about 450ft.; at the bottom of the incline there is a level constructed for about 800ft. in length, towards the boundaries of the Welcome and Homeward Bound ground, where a monkey- or auxiliary-shaft is sunk to a depth of 240ft., from which a drive has been carried for some distance. On the track of what is termed a barren lode a cross-cut has also been made, with the view of cutting the Welcome lode, but up to the time of my visit success had not attended the operations. There was, however, no defined system followed in prospecting, and it was a question to my mind if the manager knew the exact position where the lode should be met with at this depth. An air-winch has been placed at the top of the monkey-shaft, to wind the mullock from the prospecting drive.

Coming up again to the top of this monkey-shaft, and following on the same level that comes from the bottom of the incline, about 200ft. further towards the Welcome ground, the Welcome lode was cut, which is partly composed of pug and quartz, and about 2ft. in width. A winze was sunk on the lode for about 34ft. and the lode prospected for about 70ft. in length; about 60 tons of quartz taken from this place, it is said, gave 3¼oz. of gold to the ton, but, strange to say, this place where gold was said to be found was abandoned, and no attempt made to prospect the lode at a greater depth. The lode here was well defined, having good hanging- and foot-walls. A more intelligent method of prospecting will have to be adopted, or else the company will fritter away their capital and get no return.

The bottom of the lowest workings is something like 10ft. below sea-level. This is a mine that is well worthy of being prospected, and one where there appears to be a reasonable prospect of getting payable stone, by following down the strike of the lode where good ore was found in the Welcome Mine. If a connection was made from the monkey-shaft at, say, 140ft. below the top of it, with the lode in the Welcome ground, it would test the lode at that depth and give facilities for taking out a block of quartz, which is said to be payable under foot at the boundary of the Welcome and Homeward Bound ground. The connection at the present level is such that neither quartz nor mullock could be economically taken out. The entrance from the Welcome Mine is cut off, through the timber in the chamber and head-gear on the top of the shaft being burnt, which has destroyed also, in all probability, the winding-engine and boiler which stood in the chamber.

During last year calls to the extent of £3,000 have been made, which show that the present proprietors intend prospecting the ground.

Fiery Cross Mine.—The Fiery Cross Company went into liquidation, and sold their plant and mine to F. Rooney and party for £500. They were, at the time of my visit, working from the 200ft. level, at about 300ft. north of the shaft, on a block of stone about 100ft. in length, and having 130ft. of backs. The old company considered this block of stone too poor to pay for working, but the present party expected it to yield from 8dwt. to 10dwt. per ton; and they were not deceived in their expectations. From 140 tons of quartz they obtained 72oz. of gold. The lode is well defined, and will average about 3ft. in width. In some places it is 5ft. wide, and in other places it is only from 18in. to 2ft. The line of reef is the same as that worked by the Welcome Company, but the shot of gold-bearing stone is entirely different. The general strike of the lode is northerly, dipping on an average inclination of 1 in 1·7, and, as the lode at the 450ft. level is some distance from the Welcome Company's boundary, it will only be found at a very deep level should it live down to get into the Welcome ground. The general plan of the old company's workings shows that there is a much greater length of gold-bearing stone near the surface than what has been found at the 450ft. level. From this level an inclined shaft was put down, and the stone stoped out to a further depth of 245ft., thus making the deepest working in the Fiery Cross Mine 695ft. below the surface at the mouth of the shaft. There are only seven shareholders, and, judging from an examination of the mine, they have acquired a very cheap property, and have crushed 384 tons of stone, which yielded 191oz. 10dwt. of gold, having a value of £765.

There is no work being carried on in any of the other claims. The Just in Time and Reform Companies have done nothing for years, and it appears that they still hold the ground. It is only right that companies should have every latitude allowed them when they have spent considerable sums of money in prospecting, but when three or four years pass by without any work being done it is time that the ground should be thrown open to any one who chooses to work it.

Boatman's Tailings Plant.—A cyanide plant has been erected on the side of Boatman's Creek, below Caplestown, to work the tailings from the Welcome Company's battery. The result of the treatment of the tailings in the first instance was anything but satisfactory, and some began to despair of the tailings being treated successfully by the cyanide process. At that time the manager in charge of the plant complained more of the slimes amongst the tailings than anything else; but he also thought that the large percentage of antimony in the tailings had a deteriorating effect on the cyanide. He was then commencing to turn over the tailings and break up any lumps of slimes that formed a compact mass. The result of the first clearing-up after taking this precaution was that 253 tons had been treated, which had an assay-value of £317 12s., and the value recovered was £235 2s. 9d., and the value of bullion carried forward to next term was set down at £12. This made the total value of the extraction £247 2s. 9d., which is equal to 77·8 per cent. of the assay-value. The proprietors state "that the cost of cyanide per ton of ore treated was 5s. 11d., which is considered high, owing to the large proportion of antimony present. The labour was also considerable in breaking up the material to make it leach satisfactorily; but, notwithstanding this, as well as the incidental expenses, which are always somewhat heavier on an experimental run, the net profit on working was 6s. per ton." Taking this amount of clear profit per ton, the total expense connected with the treatment must have been £171 4s. 9d., and the actual profit £75 18s.

Sir Charles Russell Company.—This company has for the last three years been prospecting its claim, which is situated in the Painkiller district, and have now opened it out sufficiently to prove that there is a considerable quantity of highly payable stone in sight. A considerable amount of work was done on the upper levels, where payable stone was got, and a winze was sunk for some distance, which showed the stone to be continuing down. A main level for about 1,000ft. was then put in lower down the face of the range, and an uprise has been constructed, so as to connect the upper workings. The claim is situated back in the bush, and about a mile and a half from the road crossing the Waitahu River going to Boatman's, and the only opportunity afforded of getting any of the quartz tested was by packing it out on horseback. During last year 11 tons of quartz were crushed, which yielded 11oz. 10dwt. of gold. The lode is about 18in. in thickness. A road has been constructed for about half a mile to where the company proposes to erect a crushing battery, and tenders have been accepted for its erection. It is intended to connect the mine with the crushing battery by a tramway to bring down the stone.

Inglewood Extended Company.—This company has suspended operations for a considerable time. The lode has been stoped out above the lower main adit, and there is too much water to contend with, which prevents the sinking of a winze on the lode; and to construct a lower adit-level would be very costly. The length of the present level to where it cuts the reef is about 1,300ft., and, as the slope of the range is about 1 in 3, to construct another level would mean a distance of 1,750ft. The average length of the payable block of stone in this mine was about 120ft. The thickness of the lode was from 2ft. to 3ft., and it is said to have averaged 13dwt. of gold per ton. The bearing of the lode is about 15° to the east of north, having an underlie to the westward of about 40°, with a slight strike to the north. The track of the lode can be seen in both faces of the lower level, but there is no stone of any value for working. The company propose extending the lower level of the line of reef, with the view of picking up another shoot of gold-bearing stone. At the south end of the block the lode merges into a hard dark-green dyke-stone, with quartz and calcite veins running through it. This has been gone through for some distance, and the rock in the face of the drive gives promise that the lode will be again picked up. Gold to the value of about £22,047 has been obtained from this mine, of which £2,700 was paid in dividends; but last year calls to the amount of £250 were made.

Wealth of Nations Company.—At the end of this company's main adit, on the battery-level, a winding-shaft has been sunk to a depth of 200ft., where Seymour's patent safety-cages are used for winding, which is done by a wire rope being carried in on pulleys along on one side of the adit level from the drum on a reversible overshot water-wheel, which is used for winding, and thence carried

to the pit-head pulleys over the shaft. A level has been carried along from the bottom of the shaft for a distance of 1,030ft., and at 900ft. along this level a winze has been sunk to a depth of 150ft. The workings at the time of my visit were on a block of quartz about 30ft. from the bottom of this winze; the quartz is very bunchy. It can hardly be termed a lode, being more in the character of a "blow" or large pocket. The block of quartz is about 30ft. long and 20ft. wide, having an arm going away from it about 6ft. in width. Taking the whole length of the quartz to be about 75ft., it would average, say, about 10ft. in width. It lies almost flat in the bottom of the place where they are working, and has the appearance of an inverted saddle-lode; but it wants that defined character which lodes in general have, and which enables their trace to be followed. A great deal of prospecting work has been done in this mine, and the company deserves to have had better success than it has met with. During last year this company crushed 3,875 tons of stone, which yielded 1,162oz. gold, representing a value of £4,624.

Keep It Dark Company.—This company's main shaft is sunk down to a depth of 503ft., and a level constructed at 475ft., and at 520ft. from the main shaft; at this level a blind or monkey shaft was sunk to a further depth of 375ft., at the time of my visit, and the sinking was still being proceeded with. It was intended to go down to a depth of 400ft., and then open out a level which will be 150ft. below the No. 5, or lowest level where the workings have been carried on. From this blind shaft the lode has been stoped out, as far as payable stone is concerned, to a depth of 850ft. below the level of the mouth of the main shaft, which makes the workings about 150ft. below sea-level. A block of stone was struck in the bottom of the No. 5 level, and it is this block the company now proposes to work when the No. 6 level is completed. If gold is not found on this level the company proposes to abandon the mine, unless some assistance is obtained from Government to further test the mine at deeper levels.

This company, since it commenced to work the mine, has paid about £108,000 in dividends, but in the palmy days, when rich stone was being got, there was no reserve fund put by to carry on prospecting operations or dead-work; the principle has been to pay away all the profits, and trust to circumstances as to future developments. The time has now come when calls have to be made to carry on prospecting operations, and some of the present shareholders, who bought their shares when the yield of gold was beginning to fall off, and paid a considerable price for them, are not now in a position to pay heavy calls, and unless some gold is struck, or some assistance given, the company will in all probability suspend operations.

When in the district, some of the directors met me in reference to an application which they made to the Government for a loan, under the provisions of the "Mining Act Amendment Act, 1893." They proposed to sink the blind shaft to a further depth of 400ft., and prospect the ground at this depth. They estimate the cost of sinking this shaft at £2 15s. per foot, which would amount to £1,100; and they will require an air-winch erected near the mouth of the blind shaft to wind with. This is estimated to cost £600, and they put down £300 for contingencies, so that in all they require £2,000 to do the proposed work.

The country rock at the lowest level worked may be said, in a mining phrase, to have a "kindly appearance." It is not that hard crystalline structure that is met with in some places at that depth below the surface, neither is there any water of any consequence to contend with at this depth, so that prospecting the deep levels in this mine will not be a costly undertaking. Judging from the way in which the amount of gold decreased as the depth of the lode increased, my impression is that before another good shot of gold is obtained an entirely new lode or block of stone will have to be discovered, and the nature of the rock favours this supposition—that is, if the Maitai slate is not cut off by the Devonian formation, which is met with at Lankey's Creek, and known to be dipping towards the Keep It Dark No. 2, but the angle of the dip at this point cannot be easily ascertained.

During the past year this company has crushed 450 tons of quartz, which yielded 125oz. of gold, representing a value of £625, while calls to the extent of £2,000 have been made.

Hercules Company.—This company holds the ground formerly held by the Nil Desperandum Company, and adjoins the Keep It Dark Mine. Prospecting has been carried on in this mine for a number of years without being successful in finding payable stone. Last year, after driving about 180ft. from the bottom of the shaft on No. 8 level, without cutting the lode, an uprise was made for 62ft., when a block of stone was discovered about 5ft. in thickness; but this block was soon worked out. Prospecting was carried on, to prove if the stone lived down, but so far it has not been found to do so. During the past year 1,092 tons of stone were crushed, which yielded 791oz. of gold, representing a value of £3,164, out of which £1,500 was paid in dividends.

Keep It Dark No. 2 Company.—The operations of this company at the time of my visit were confined to the 450ft. level, which was in course of construction. The lode in the company's ground is stoped out down to a depth of 283ft., and from this level a winze was put down on the lode to a depth of 117ft., and a portion of the lode stoped out from this winze. From the bottom of the shaft at 450ft. a cross-cut was put in for 155ft. to the line of reef, thence the line of reef was followed for a distance of 74ft., but it is merely the track of a lode. The manager expected to have to go about 200ft. further before getting under the block of stone that was worked from the intermediate level put in from the winze. The bearing of the line of the lode was about 24° to the west of north, and dipping westerly at an angle of from 60° to 70°.

Globe Company.—This company has crushed a considerable quantity of stone during the last year, but it has not been of a highly payable character. From 7,330 tons, 2,539oz. gold was obtained, representing a value of £10,156. The workings have been carried on from No. 5 level in the stopes between this and No. 4 level; but the lode is now pretty well taken out, and a good deal of dead-work in prospecting will have to be done before any good stone is again opened up. The main shaft has been sunk a further depth of 200ft., and a level is being driven from near the bottom to intersect the line of reef. A winze was sunk down on the lode from No. 5 level to a depth of

150ft.; but the stone in this winze was of low grade. So that, unless a good shot of gold-bearing stone be found in the lower level, the prospects of the mine at this depth are not at the present time particularly bright. Prospecting, however, is being carried on by the extension of the No. 1 level, with a view of picking up another shot of gold-bearing stone, and, as the country rock is of a very favourable character, it is probable that another payable block of stone may be got in this direction. The total quantity of quartz crushed from the mine has been 67,363 tons, which has yielded 32,949oz. gold, representing a value of £130,618, of which amount £40,000 has been paid in dividends.

Progress Company.—This company has been fairly successful in carrying on its operations during the past year. From 8,200 tons of quartz 5,099oz. gold was obtained, representing a value of £20,396, out of which £4,800 have been distributed in dividends. The total quantity of quartz crushed from this mine amounts to 44,445 tons, which has yielded 20,651oz. gold, representing a value of £82,652, out of which dividends to the value of £13,200 have been paid. There is a large body of stone in the lode. In some places it was as much as 20ft. in thickness, and on the No. 4 level it averages about 9ft. thick, and all of a payable quality. It is a question whether the stone at the No. 5 level will prove equal to that found at No. 4 level, but this will soon be proved beyond doubt. The company has a good crushing plant; but the gold-saving appliances are not all that could be desired for the character of ore there is to deal with, there being a good deal of pyrites in the stone, and, from information supplied me, it is rich in gold. This should be carefully concentrated and subjected to proper treatment, in order to get a fair percentage of the precious metal it contains.

Golden Lead Company.—This company's mining operations are carried on at Merrijigs. Auriferous leaders of quartz were found in a sandstone formation, and it was thought, when first discovered, that these leaders were through the hill, but after working on the surface it was found that the gold was principally confined to a small lode. This lode has been worked down for about 150ft., and good stone is still found in the bottom of the level. The general character of the lode material has, however, been very poor; indeed, it may be said the ground is too good to be given up, and at the same time not sufficiently rich to pay for working. During the year ended the 31st March last, 2,435 tons of stone were crushed, which yielded 465oz. gold, representing a value of £1,890 9s. 8d. This is equal to an average yield of about 3dwt. 18gr. gold to the ton. When it is taken into consideration that the lode is only a few inches wide in places, and scarcely anywhere 15in. wide, the mine has to be worked by strict economy to make ends meet. At the present time a low adit-level is being constructed to cut the lode about 400ft. below the present workings. This adit, at the time of my visit, was constructed for a distance of 604ft. through very hard rock, and has still another 700ft. to go before it is in sufficiently to cut the lode. Last year calls to the extent of £900 had to be made to carry on the operations of the company. If the company is successful in finding payable stone in this low-level adit it will be the means of giving a new life to the district.

Cumberland Company.—This company's mine adjoins the Golden Lead Company's ground. So far the operations of this company have been very successful. Since the mine was opened 11,550 tons of stone have been crushed, which yielded 9,810oz. gold, representing a value of £40,233, of which amount £13,200 has been paid in dividends. The lode between No. 1 and No. 2 levels has been stoped out, and an incline shaft sunk down to a depth of nearly 80ft., but at the bottom of the incline the lode was greatly broken up, and not payable for working. All the original block of payable stone has now been taken out, and on driving a cross-cut to the southward from the bottom of the incline for a distance of about 40ft. a new lode was cut, which averaged at this level about 18in. in thickness. A winze has been sunk on the lode to a depth of 45ft., where its average thickness is about 2ft., and the stone of fair quality. During the past year 3,575 tons of quartz have been crushed, which yielded 2,475oz. gold, representing a value of £9,900, out of which dividends were paid to the extent of £2,400.

Sir Francis Drake Company.—This company has not been successful in carrying on mining operations, during the past year. From 1,911 tons of quartz, 393oz. gold were obtained, representing a value of £1,482; but this did not pay for the expense of working, as calls to the extent of £1,800 had to be made during the year.

Big River Company.—This has been the most successful company in the Reefton district during the past year. From 2,190 tons of quartz 4,371oz. of gold was obtained, representing a value of £17,484, out of which £9,900 was paid in dividends. During the last year the shaft has been sunk from No. 3 level for 120ft., and a cross-cut has been driven for 100ft. to intersect the winze, which was sunk on a block of good stone. The lode at this level has been driven on for a distance of nearly 80ft., and averages about 6ft. in thickness. A winze has been sunk down below this level for a depth of 84ft., and the lode still continues about the same thickness and quality. A contract has been let to sink the shaft another 120ft., which, when completed, will reach a total depth of 775ft. from the surface. The total quantity of quartz crushed from this mine is 7,301 tons, which have yielded 11,642oz. of gold, representing a value of £46,535 16s. 11d., out of which £23,700 has been paid to the shareholders in dividends.

This is a portion of the district where comparatively little prospecting has been done. Claims have been taken up from time to time, and a little money expended on them; but, with the exception of the Big River Company's claims, no gold-bearing stone of any note has been found. At the same time, in the locality where such rich stone exists other gold-bearing loads will yet be found.

Lyell District.

The principal mining operations carried on in this district is by the Alpine Company, who have about forty-seven men employed in connection with the mine and battery. The operations are now

confined to No. 7 level, which is about 852ft. below the surface at the place where the lode is worked. An incline shaft is sunk below this level to a vertical depth of about 132ft., and the company were opening out a level at this depth to work the lode at the time of my visit. The lode in this mine is from 6ft. to 9ft. in thickness, and averages about 17½dwt. of gold to the ton. During the last year 9,669 tons of quartz were crushed, which yielded 8,246oz. gold, representing a value of £32,984, out of which regular dividends are paid to the shareholders. This is a mine which, judging from the stone in sight, ought to be a dividend-paying one for the next two years.

Larnach Company.—This company has been engaged for many years in the construction of an adit-level, which is now in for a distance of about 3,200ft., and a cross-cut was constructed for some distance, where a strong lode was cut, showing gold, which is considered payable for working, it is thought, to the Alpine North Block. The company deserve credit for its perseverance in constructing this long adit, which will be yet a valuable highway, not only to work this mine, but also to work the Alpine Mine at lower levels.

United Italy Company.—Only a few men have been working in this company's mine during the last year. The lodes are very small, but occasionally very rich stone is obtained. During the last year 108 tons of quartz was crushed, which yielded 612oz. gold, representing a value of £2,448.

Crœsus Mine.—A party of miners have taken up this mine, which has been abandoned for several years, and have been carrying on prospecting operations. During the last year they had 78 tons of quartz crushed, which yielded 52oz. gold, representing a value of £208.

Tyrconnel Mine.—There is no large body of stone in this mine. The gold is found in small quartz veins and leaders, some of which are very rich. During the past year only 21 tons of stone was crushed, but this yielded 276oz. gold, which is equal to over 13oz. gold to the ton. Although the quantity of quartz obtained from this mine is small, the yearly returns show that it is a payable venture for the number of men employed in connection with it.

The following are the returns from the different crushing batteries on the West Coast, including Collingwood, for the year ending the 31st March, 1894:—

West Coast Battery Returns.

Battery.	Quartz crushed.	Amalgam.	Retorted Gold.
	Tons.	Oz.	Oz.
Collingwood—Johnstone's United	4,561	2,257	914
Reefton—			
Venus Extended	1,113	1,943	647
Venus Extended, for Royal	410	1,064	358
Venus Extended, for Energy	339	300	87
Wealth of Nations	3,875	3,695	1,162
Minerva	228	256	120
Golden Point	58	43	12
Golden Fleece	406	454	167
D. Yorwarth's battery	82	...	82
	6,511	7,755	2,635
Boatman's—			
Fiery Cross	384	570	192
Fiery Cross, for Duffy Brothers	10	23	15
Fiery Cross, for Pactolus	14	53	20
Fiery Cross, for Argus (tributers)	9	7	...
Fiery Cross, for Argus (tailings)	7	7	4
	424	660	231
Murray Creek—Golden Treasure, for Victoria ...	195	263	114
Crushington—			
Keep It Dark	450	396	125
Keep It Dark, tailings	...	18	5½
Keep It Dark, for Sir Charles Russell ...	11	38	11
Keep It Dark, for No. 2 South	105	230	70
Keep It Dark, for Hercules	1,092	2,442	791
	1,658	3,124	1,002½
Devil's Creek—			
Globe	7,330	7,959	2,539
Progress	8,200	15,291	5,099
	15,530	23,250	7,638

WEST COAST BATTERY RETURNS—*continued.*

Battery.	Quartz crushed.	Amalgam.	Retorted Gold.
	Tons.	Oz.	Oz.
Merrijigs—			
Golden Lead	2,435	1,223	465
Sir Francis Drake	1,911	1,270	393
Sir Francis Drake, for A1	6	76	34
Sir Francis Drake, for Gallant	59	28	9
Cumberland	3,575	7,109	2,475
	7,986	9,706	3,376
Big River	2,910	12,282	4,371
Lyell—			
United Italy	108	. .	612
Crœsus	78	69	52
Crœsus, for Tyrconnel	21	510	276
United Alpine	9,669	21,341	8,246
	9,876	21,920	9,186
Grand totals	49,651	81,217	29,467½

WESTLAND DISTRICT.

There is no quartz-mining of any note in the Westland District. A few men are working a small leader of quartz at Donnelly's Creek at the place where gold was found in small veins of quartz over twenty-five years ago; but, from the information received when in this portion of the district, the returns from the working of the ground do not pay wages after the other expenses are paid.

Adjoining this claim, higher up the creek, another claim is taken up, and prospecting operations have for some time been carried on by a party receiving a subsidy from Government; but no payable stone had been got here up to the time of my visit in May last. About half a mile from the same place, but on another terrace, C. Porter has been constructing a low-level adit, with the view of cutting a lode which he worked on a higher level, giving an average of about 1oz. of gold to the ton. This adit is not yet sufficiently far ahead to cut this lode.

At Cedar Creek, prospecting operations are being carried on in the William Tell Claim, but so far nothing of any value has been discovered. This is a likely-looking country for auriferous lodes to exist in, and it is to be hoped that success will attend the labours of the present party carrying on the prospecting-work.

At Constitution Hill, Antonio Zala has been prospecting for years, and is said to have got a little gold, but nothing to warrant the erection of machinery. The difficulty of access to this place is a great drawback to prospecting operations being carried on.

OTAGO DISTRICT.

Nenthorn and Barewood.—There are a few miners working quartz lodes in these localities, but the returns do not show this class of mining to be in a flourishing condition. At the Bonanza Mine, a low-level adit has been constructed for a distance of 900ft., of which 400ft. is following the line or track of the lode worked on the upper levels. At 800ft. in from the mouth of the adit an uprise was constructed for 75ft., following quartz all the way. The thickness of the lode seems to increase on rising on it. At the same time it is very small, but contains a fair quantity of stone. During the year 125 tons of quartz were crushed, which yielded 114oz. of gold, representing a value of about £451.

At the Surprise Reef, Nenthorn, there are four men at work. The auriferous leader that is being worked is very small, varying from 2in. to 8in. in thickness. The country rock is very hard, and stands remarkably well without timber, but unless something better be discovered the working here will soon cease. About nine months ago Mr. J. Holden went into an old shaft in the old Consolidated Claim and found some quartz, which he followed down for 65ft., the leader being from 3in. to 1ft. 6in. in thickness. Although small, it has paid very well for working. He had 66 tons of quartz crushed, which yielded 159oz. of gold, representing a value of about £628. Another crushing has been taken out, but the results are not yet made known. The total quantity of quartz crushed from Nenthorn last year was 1,599 tons, which yielded 537oz. of gold, representing a value of £2,121.

Barewood Company's Mine.—This mine was worked on tribute by Messrs. Hawkins and Porter during the past year, but has since been abandoned by them, as they cannot get sufficient returns to pay wages and expenses. The manager of the company is making alterations and improvements in connection with the crushing battery and mine, so as to carry on operations systematically. The intention is to sink the shaft to a greater depth, and put in a level to take out the lode below the present workings. The lode at the bottom of the shaft is about 2ft. 6in. in thickness, and is considered payable for working. On the foot-wall side of the lode it is intermixed with scheelite, which

may be found to be more valuable than the auriferous stone, as great inquiries are made respecting this mineral by Messrs. Blackwood and Co., of Liverpool and London, who some time ago were offering 10s. per unit for scheelite.

Donald Reid's Mine.—A shaft has been sunk following the reef to a depth of 150ft., and the lode is said to be 2ft. 6in. in thickness, and carrying sufficient gold to give good returns for working. During the last year 1,447 tons of stone have been crushed, which yielded 549oz. of gold, representing a value of about £2,139.

Hindon.—A party of three men took up the Gladstone Mine about two years ago. They have been working on a lode about 18in. in width, which gives an average of about 6dwt. gold per ton, and this gives them small wages. No work has been done at Bigg and Wilkinson's mine during the year.

Waipori.

The quartz workings in this locality are very limited. Indeed, it cannot be said that ever there were extensive workings on quartz lodes here, although several lodes have been worked, and a fair amount of gold obtained. The greatest amount of work has been done on the old O P Q reef, where the first quartz-mine was opened in the Waipori district. The lode was found cropping out on the surface on the old road leading from Weatherstone's to the West Taieri, *viâ* Maungatua. The quartz was never particularly rich, but, the lode being a good width, it gave during a good many years fair results for working. It has been stoped out to a depth of about 100ft. for a distance of about 150 yards, and for a short distance to a depth of 100ft. below this. The lode was originally worked by the O P Q Company, but this company has abandoned it for some years past, and the only party now at work is Mr. Ritchie and party of four men. They are driving an adit on the line of lode, with the view of working it at a greater depth than previously. At the time of my visit, in conjunction with Mr. R. A. Murray, F.G.S., the Chief of the Geological Staff in Victoria, and Mr. A. McKay, F.G.S., Mining Geologist, the adit was constructed for a distance of about 300ft., and in the face of the drive there was a thin leader of quartz showing gold. The hanging-wall was well defined, but on the foot-wall side the quartz seemed to merge into the country rock. The party expected to have to drive another 100ft. before they got under the place where the shot of gold was found on the upper levels.

A shaft has been sunk in a gully a short distance from the mouth of Mr. Ritchie and party's adit-level to a depth of about 200ft., and is said to have cut the lode, which was a good thickness, and carrying a little gold, but the quantity of water there was to contend with was too great, and the shaft is now abandoned. Other claims have been worked on the line of reef with varying success. A shaft was put down about half a mile south of the present workings, where, it is said, sufficient gold was found to pay for working; but, if that was so, it is strange that the whole of the ground is now abandoned.

The quartz lodes here resemble to some extent those found at Nenthorn, and, so far as they have been proved, the gold gradually gets less as the lodes increase in depth, and, as a rule, the width of the lodes also lessens. It therefore becomes a very moot question whether payable gold will be found in the lodes at a great depth. It has never been tested, but, judging from the large area of quartzose-schist formation in this locality, there is little likelihood of very rich auriferous quartz being obtained.

Bald Hill Range.

On this range, opposite Spear-grass Flat, there are two quartz claims being worked. One of these was opened by White's Company, who went into liquidation, and it was purchased by Messrs. Syme Brothers, who were both mine-managers to the former company. The most of the stone has been stoped out from the old workings above the adit-level, and some of the lode has been taken out under foot. During the last year a shaft was put down ahead of the old workings, and a lode discovered about 30ft. from the surface. Sinking is still being continued on the lode, which is about 2ft. in thickness. A drive is being put in from the old workings, at about 70ft. below the surface, to cut the new block of stone, so that it can be run through the adit to the battery, which is erected close alongside the mouth of the adit-level. Only 57 tons of quartz was crushed last year, which yielded 40oz. gold.

The Excelsior Mine is about one mile to southward of White's Reef, and is worked by the prospectors, Messrs. Crossan and Gray. There are now four men employed in this mine, and the lode is 3ft. to 8ft. in thickness. Some portions of the lode resemble decomposed quartz, or rotten granite mixed with sand and clay, but some of it is very rich, and yields 2oz. of gold to the ton. The depth of the present workings is about 30ft., but the lode has been sunk on to a depth of 60ft. About 279 tons of quartz has been crushed during the past year, which yielded 598oz. gold, representing a value of £2,360. The claims on this range, being at a very high elevation, can only be worked for about eight months of the year.

Rough Ridge.

A small quantity of gold has been obtained out of mines known as the Progress and Great Eastern. About four years ago these mines were offered on the London market, but no one would take them up at the price then wanted for them. They were then worked again for a short time with success, but, the block being worked out where payable stone was obtained, operations were suspended, and the properties fell into the hands of the mortgagees, who sold them to Perry and party for £325. At the time of the sale there were seven shareholders in the party, but five of these have since abandoned the property, or, at least, left off working the ground. Only Mr. Perry and another are now working the ground.

Mr. Perry was working in the Great Eastern Mine for a long time when it was the property of the company, and he states that from October, 1887, to March, 1889, gold was obtained to the

value of £3,808. A shaft is sunk following the continuation of the lode from the surface down to a depth of 235ft. The upper 30ft. of the shaft is nearly vertical, but below this it has a considerable incline.

An adit has been constructed from the face of the terrace, which strikes the shaft at 30ft. below the surface, and extends for about 90ft. beyond the shaft on the lode, which averages about 15in. wide. Levels have also been constructed at 90ft., and from the bottom of the shaft at 235ft. At the 90ft. level the lode has been stoped out for between 300ft. and 400ft. in length, and at the bottom level the lode is stoped out for a length of about 240ft. In both these levels faults were met with, which caused a disarrangement of the lode, throwing it as much as about 50ft. out of its original line. Several of these faults were met with, although the heave was not so great in some of them, and to some extent they had an effect on the quantity of gold in the stone at the two first faults met with. Good gold was got up to the slides, but on the last one met with the gold was entirely cut off.

At the Progress Mine an adit-level has been constructed from the bottom of the gully for a distance of about 400ft., and other levels have been constructed above this, and the lode partially stoped out. From the lower adit-level a winze was sunk for a distance of 40ft., and the payable portion of the lode stoped out to this depth.

Mr. Perry now proposes to work the Great Eastern Mine, and get a suitable pump to effect the drainage, and also to erect winding gear. He further proposes to extend the bottom to the north-west and south-east, for which purpose he applied for a loan of £1,000 under the Mining Act Amendment Act of 1893. There is a battery of five heads of stamps on the ground, driven by a turbine water-wheel. There is also a small steam-engine, with boiler, on the ground, but this is not used now, on account of having water as a motive-power.

Cromwell.

The only work of any consequence that is being carried on in quartz reefing is at New Bendigo by the Cromwell Company. This company has sunk a new shaft to a depth of 534ft.; a level has been constructed at 520ft. by a cross-cut from the shaft, 185ft. in length; and about 500ft. has been driven on the lode, which is in most places only from 6in. to 8in. in width. The walls are well defined; and, from what the manager states, the lode in the upper workings in places pinched out to a few inches and then made again. So far, however, no stone payable for working has yet been found at the lower level. The old workings were carried down to a depth of 420ft., and worked for 1,000ft. along the lode near the surface, and for 600ft. long down to the depth stated, with the exceptions of some blocks that were left, which were not considered payable for taking out. The lode on the upper places was as much as 6ft. wide, but, taking the average, it would be about from 2ft. to 3ft. At the lower level, however, in the new shaft, it does not exceed 2ft. 6in. wide in any one place, and pinches to a thin leader of quartz about 2in. thick on the east end, and to a mere track on the west end. The country rock is a highly indurated quartz schist.

Workings at the deep level were suspended at the time of my visit, they being all confined to the upper level, where some blocks of stone had been left in the early days; but there are only a few men employed. At the low levels there is comparatively little water to contend with; a 9in. pump is sufficient to keep the mine dry. The pumping is done by three lifts—namely, two plungers and one draw-lift—the heights to which each pump lifts being respectively 250ft., 214ft., and 70ft.

In regard to the likelihood of gold being obtained at the 520ft. level, there is only a faint chance of another shot of gold-bearing quartz being discovered. The present shot having extended a great length, there is a likelihood of there being a good block of barren ground before the next shot is reached. There were several claims worked on this line of reef to the westward of the Cromwell Company's ground, and some fair auriferous stone was found; therefore, there is a probability, by continuing the level on the line of the lode to the westward, notwithstanding that the quartz may cut entirely out, so long as the track of the lode is plainly seen with two well-defined walls—there is always a probability of the lode being again recovered. It is the class of lode that is well worthy of being prospected, but beyond prospecting there is nothing immediately in view to show that the quartz-workings can be carried on with a profit. The company having a plant on the ground, with water as a motive-power, ought not to stop before the mine is prospected by driving along the lode, and also testing it at a deeper level. If at another 200ft. level the lode continues to pinch out, or there be no gold in the stone, it would then be time to consider the advisability of abandoning the mine.

Macetown.

Quartz-mining about Macetown continues to progress slowly. Some of the mines are, however, getting more opened up, and it is to be hoped that those who have lately invested their money in reconstructed companies will get good returns for their outlay. For some years the mines have been worked from hand to mouth—that is, the gold obtained was expected to pay all expenses of dead-work and develop the mine; but, after paying the expense of actually stoping-out the lode in sight, there was very little left to carry on prospecting operations. The Premier and the Tipperary Mines have now become the property of English companies, who are spending a good deal of money in opening them up, and effecting improvements whereby the cost of mining and crushing will be considerably less in the future than it has been in the past, and this will admit of lower-grade ore being made to pay for working. It is of the utmost importance to the mining industry that people supplying foreign capital should get a fair percentage for the money invested. We have not sufficient capital in the colony to properly develop our quartz-mines, more especially as many of them are getting to a considerable depth. The upper levels being all stoped-out, deep shafts and expensive adits have to be constructed before any returns can be expected. Improved machinery has to be provided, to procure which many of the companies now in existence have not the means. These companies will have to be reorganized, and outside capital obtained. It therefore behoves

any one who is interested in the mining industry to refrain from advocating or sanctioning any scheme that will tend to develop mining unless there are strong reasons to believe that the undertaking proposed will become an investment which will at least repay small interest on the outlay. And if it could be shown to English capitalists that mining ventures in this colony would give them a fair return for their money, mining would soon become in a more flourishing state.

Capital has been obtained from England to open up and develop the mines at Macetown, and it is to be hoped that the shareholders in these mines will realise their expectations. The advertisement inviting people to take up shares in the West Argentine Company, which is a reorganization or reconstruction of the Tipperary Company, as published in the *Financial Daily News*, of London, states in glowing colours what people may expect by investing in shares in this company; but some of the investments which appear well on paper are never realised, and, if not, this has a very bad effect in causing really good ventures to be looked on with distrust. Without making any comment on the mine referred to, the following prospectus or advertisement will speak for itself:—

"*Prospectus of the West Argentine Gold Company (Limited).*"—The *Financial News* of the 28th December, 1893 (the leading London daily financial paper), states,—

"The *Otago Daily Times*, one of the most important daily papers in New Zealand, may be taken as most valuable testimony as to the character of local opinion on the subject.

"'The new find in Tipperary Mine,' says the Otago *Times*, 'although only recently made, is of such a nature as will greatly enhance the value of the property, to what extent it is at present quite impossible to say; but the sequel will show what a few feet of cross-cutting may do. About 60ft. or 70ft. from the mouth of the old main adit of the mine a cross-cut had been put in for about 14ft., in a northerly direction. The same cross-cut was being extended by the new management, when, before 4ft. had been driven, a shoot of stone was struck that fairly glittered with specks of the precious metal. The lode, which at this point is very friable, was found to be between 4ft. and 5ft. wide, carrying gold throughout the whole width. A portion of the lode, estimated at about 2ft. wide, ranks with, if it does not excel, anything of the kind ever seen at Macetown. Miners whose judgment of the yielding capabilities of quartz is entitled to respect, fix its value at from 2oz. to 3oz. per ton. However, if the whole width of the lode is taken, and, say, it averages 1oz. per ton, the new find will in itself mean a fortune to the shareholders. Mr. W. Stanford is now opening the lode by a rise, and driving upon its course in a horizontal direction going east—that is, into the hill. There is every sign that the lode lives down. The lode carries good solid walls, and shows all the signs which generally, and at Macetown especially, indicate the permanency of lodes. The loose and friable nature of the quartz is accounted for by its nearness to the surface; and as the lode is followed further into the hill, or in a vertical direction, it will no doubt change into more solid stone.'"

As regards the opinion in City circles of West Argentine shares, the following, also from the *Financial News*, is important:—

"The tendency of speculation in the mining market is clearly towards the cheap shares—preferably those selling at rubbish prices, in which the risk of loss is infinitesimal, while the margin of possible profit is considerable. In several instances their experience has already justified the predilection of the public for cheap stuff, and in other cases there is a fair prospect of similarly good results. West Argentines, for example, are now selling at about 2s., at which price the property of the company, situated in New Zealand, and including a lode which is said to average 4oz. of gold to the ton, stands at £15,000. Assuming that the yield is only one-fourth of that figure, the property is certainly worth more than that, without taking into account a second lode, of which the manager reports in glowing terms. It is in these cheap shares of reconstructed properties that small investors find their best opportunities of quick returns.

"The mine is fully equipped with machinery, and the battery of stamps is capable of crushing 400 tons per month, and, as 1oz. per ton of quartz should yield a profit of £2 10s. per ton, it follows that at this low rate the mine should again shortly be in a position to make profits, and this time at the rate of £1,000 per month, equal to £12,000 per annum, calculated on 1oz. of gold per ton of quartz; but, in view of the recent discovery, estimated to yield 4oz. per ton, the cost being the same—namely, £1 5s. per ton—a profit of £4,000 monthly would be realised, equal to £48,000 per annum; and West Argentine shares may rise from their present low value to £1. West Argentine shares should accordingly be bought. On the above calculation, an investment of £10 may become £100, and so on in proportion."

The advertisement, or prospectus, or by whatever name one would term this document, which appeared under the head of advertisements in the *Financial News*, of London, of the 28th December last, was certainly a most ingenious composition. The actual result of working this new discovery referred to was that a large expenditure was made in laying down a ground-tramway from the adit-level to the crushing battery, and after crushing 600 tons of quartz a yield of 36oz. of gold was obtained, which is equal to about 1dwt. 5gr. of gold per ton, having a value of 4s. 4d. per ton, which shows, instead of making a profit on the working of the mine, there is a considerable loss. At the time of my visit a low-level adit was in course of construction, and was in for about 320ft. The total length of adit required to be constructed before it will reach under the old workings is about 1,800ft., when it will be about 15ft. under them. All work on the upper levels was suspended at the time of my visit. Only seven men were employed.

Premier Company.—This is one of the Glenrock Company's properties. This company has recently been reconstructed, with a nominal capital of £225,000, which is divided into 225,000 shares of £1 each, each shareholder in the original company to have the option of taking up shares in the new company within fourteen days from the date of the notice calling on them to do so. They were to be credited with 19s. as being paid. They had to pay 6d. per share on application, and the other 6d. per share was not to be called up within twelve months. Although the original company were part proprietors of the Premier Mine, it had not sufficient capital to develop

it. A manager (Mr. W. Stanford) had come out from England to manage the property, and he required £5,000 to develop it. The reason Mr. G. F. Travenor, the chairman of the Glenrock Company, gave for reconstruction was the glowing reports that he had received from the manager of the Premier Mine, which goes on to state, after giving full details of the property, "And now, gentlemen, to sum up, I believe the Premier Mine will prove to be one of the finest mines in the world. To carry out this work, however, capital must be sunk. Time is all-important, and the sooner this work is started the cheaper it will prove to be. I believe I see my way, before this day twelve months, to ask you for a new battery, of at least 100 stamps, and all the capital I ask you to put into my hands for development is the small sum of £5,000. It is no use expecting me to work any longer on the present system. Every one here is soundly asleep, and it is out of my power to awaken them unless I have money in hand to pay off a man, or gang of men, at a moment's notice. The work underground is costing a fortune at present—some of it up to £5 and £6 per foot. The men do not care, and it is impossible for me to urge them when they know they cannot be dismissed, no matter what they do. It is simply marvellous that work should have gone on so long and the mine survived such a system at all."

According to the report of Mr. Stanford, the workmen in the mine were not in an enviable position. They must have been working for a long time without getting any wages. This statement is borne out by another paragraph in the report referred to, wherein Mr. Stanford states, "I find that for some months past Mr. Elliott"—who is the mine-manager—"has carried on the work with a staff of men from week to week, and from month to month, partly at his own expense, and the rest at the expense of Messrs. Reid and McDowell, the local storekeepers. The men, I am told, have worked on trust for months together without wages."

To employ men and not provide for the regular payment of wages is bad in principle. Men become discontented, and more especially when they are working for a foreign company, and not aware in what position it is in; and this state of things fully justified the manager in demanding money to carry on the work.

The Premier Mine, no doubt, in the past has not been opened out in such a manner as to allow the mine to be worked in the most economical manner, but this was due not so much to the management as to the scarcity of funds to do any dead-work. The original shareholders of the late Premier Company did not consider it advisable to call up any capital to develop the mine. They sold the property to the Glenrock Company, retaining a certain number of paid-up shares. As soon as this was effected, a low-level adit was commenced, and this adit was driven partly from the outside and partly from the bottom of a winze. The result is that the adit winds about in a sinuous course, instead of being driven in a straight line until it cuts the lode.

There are four distinct lodes in this mine. Some of them may be termed "leaders," in which gold was found in the upper levels, but they do not appear to go down, or, at least, they have not all been found at the main adit-level. The main lode is from 4ft. to 6ft. in thickness, but the shot of gold-bearing stone is very small; it only runs for a distance of about 40ft., having a north-westerly strike of about 25° from the horizon, and dips to the south-west. The walls of the lode are exceedingly well defined, but, instead of the parting or fissure being filled with quartz, there is mullock, having a little quartz mixed with it in places. Judging from the appearance of the lodes at the level of the main adit, there will not be a large supply of stone for the crushing-mill for some time. However, this company has the Sunrise Mine, on Advance Peak, where gold was got near the surface, and probably, if prospecting were carried on in this mine, some good shots of gold-bearing stone would again be found.

At the time of my visit the company were erecting an additional ten heads of stamps to the mill, or, it may be said, the foundations were being put down for the erection either of a new ten-head battery or the re-erection of the ten heads that were purchased from the Sunrise Company, which is erected a few chains lower down the creek, and was being used by the company at the time of my visit. The old battery has been repaired, and blanket tables substituted for silvered copper plates. A small cyanide plant to treat the concentrates from the blankets has been erected. This consists of two circular solution vats, one sump, and a tank for making the solution up to the required strength. Sixty-three tons of concentrates have been treated, which gave gold to the value of £500. This would indicate about 125oz. of gold extracted. The concentrates, therefore, yielded about 2oz. gold to the ton. The manager states that there is from 1 per cent. to 4 per cent. of pyrites in the ore.

The Premier Mine is about 3,300ft. above sea-level. The frost in winter is, therefore, very severe, and prevents the crushing battery from being worked for several months. This causes the suspension of operations in the mine. The present manager, however, in his report to the directors in London, states that he has provided heating apparatus for the interior of the mill, so that nothing but a heavy fall of snow will prevent the crushing battery working day and night in future. The high elevation at which the mill is situated, and the severity of the frost during the winter months, will turn the water in the supply-race into ice, and thereby cut off the motive-power for driving the machinery, and this no heating apparatus in the mill will prevent.

During the past year 3,163 tons of quartz have been crushed, which yielded 1,985 oz. gold.

Shotover.

There is only one mine in this locality, the Gallant Tipperary. The operations are being carried on about 20ft. above the intermediate level, the lode being about 2ft. 6in. in thickness, and the shot of gold about 300ft. in length, and, if it continues up to the surface, there will be 200ft. of backs. The lode dips about one in five, and averages about 10dwt. per ton. With six men working in the stopes they get about 40 tons of stone per week, which is about the quantity that the crushing battery will put through, working in the day-time. The manager estimates that he has four years' work in sight, and if the stone keeps up to the average yield of last year the mine should be a good property. The expense in crushing is very small, as there is an abundance of

water in ordinary seasons for motive-power. During the last year 731 tons of quartz were crushed, for a yield of 376oz. gold.

Skipper's.

The only quartz-mine at Skipper's is that belonging to the Phœnix Company. The mine and plant was taken over from Mr. Bullen on the 31st March, 1893, by the Achilles Gold-mining Company, which was formed in London with a capital of £100,000, in £1 shares, but up to the time of my visit no money had been sent out to carry on operations or to do any prospecting work. The manager, having in view the formation of the new company, refrained from carrying on prospecting operations to any great extent, and when the new company took the property over there was a considerable amount of dead-work to do before the mine could be properly opened out, and this necessitated extra expenditure, which the returns from the mine were insufficient to meet. As the company had not sent any money out, the workmen did not get any wages for some months, and they then applied to Mr. Bullen for payment, and he at once forwarded money to pay any one who wished to leave the work.

The shaft from which mining operations are carried on is 150ft. in depth, and an incline shaft is put down on the main lode below this level for a depth of 90ft. The incline shaft is carried down at an angle of 39° from the horizon. Formerly there were four lodes in this mine, but the north and middle lodes have come together, and the south and main lodes are now one at the lower levels. The main lode, in following down the incline, was 8ft. in width for some distance, and then contracted to about 6in., when it afterwards widened out again, and at the bottom of the well it is about 3ft. in width. From the bottom of the incline a cross-cut was made to the north lode, but after cutting it and driving on it for some distance eastward there was little or no gold. There is a small percentage of gold in the laminated quartz schist, but not sufficient to be payable for working.

A considerable amount of dead-work will yet have to be done in this mine, and an improved method adopted for working the lodes at a lower level before any large returns can be expected. From the 1st April last year to January last 1,989 tons of quartz had been crushed, for a yield of 610oz. melted gold, showing that the quartz only averaged 6dwt. 3·2gr. of gold per ton. This mine is one of the oldest in the colony. It has been worked since 1863, and, as far as can be ascertained, the total quantity of gold prodnced up to January last is only 26,417oz., which is not equal to the value of the dividends paid either by the Keep it Dark or Welcome Companies at Reefton.

West Coast Sounds.

Wilson River.—From the time I visited this district in January, 1893, to November last there has been very little work done in the quartz claims. Every one seemed to be waiting for their neighbours adjoining them to prospect the ground.

Golden Site Company.—This company holds the property better known as the Prospectors' Claim. Several huts had been built and preliminary work started at the time of my last visit, but nothing further was known regarding the lode found by the Prospectors. But since my visit there has been about twenty-seven men employed by this company in constructing a head-water race for the purpose of bringing in a supply of water from the river as a motive-power to drive crushing machinery which is proposed to be erected. Excavations for the foundations of the battery and buildings are being proceeded with, and arrangements have been made to get the machinery conveyed on sledges over the cutting and formation which was made for laying down a tramway from Cromarty to the reefs. The head-water race, which is in course of construction, is said to be capable of conveying 17 sluice-heads of water, and possibly it may do this if constructed on a uniform grade; but, unless the race be properly laid out, with grade pegs put in at short distances apart, the levels are not adhered to in its construction.

A shaft is being sunk on the north side of the river to work and test the lode at a deeper level, and an adit is being constructed on the south side of the river to work the ground in that direction. The adit, however, will not be of much use for working the ground on the south side, as there is very little height of backs to the surface. The adit has, however, cut the lode, which is about 8ft. wide at the point where it was intersected, carrying a very fair quantity of gold. The workings on the south side—at least, that portion of them that are under the floor of the adit now being driven—will have to be carried on from the main shaft which is being constructed on the north side of the river. A track has been made from the termination of the tramway to the machine site, and all preparations are being made for the erection of the machinery.

Hesperides Company.—This company has sunk a shaft to a depth of 70ft., and from this, driving has been done to the extent of about 90ft.; but success has not attended the company's operations at this particular place, and prospecting has been commenced near the southern boundary of the claim, two men being employed.

Surprise Claim.—A good deal of work has been done in this claim on the surface, and a reef found about 2ft. wide, carrying a little gold. The holders are trying to form a syndicate or company for the purpose of working it.

Lucky Shot Claim.—There were two men employed for a few weeks prospecting this claim, but, as they were not successful in finding any payable stone, work on the claim has been suspended.

Rata Claim.—This is situated at the south bonndary of the Lucky Shot Claim. One man has been at work trenching the surface, but, so far, has not been successful in finding any gold.

There is also a claim in the river-bed in the Golden Site licensed holding, which a man has taken up as a river claim, but he intends to work the quartz below the river-bed if he can legally do so. This will make the working of the Golden Site ground a dangerous operation, as the river may get into the workings, and endanger the lives of the workmen. On no account should a person be allowed to sink in the bed of the river to take out a quartz lode where people are working in the adjoining mine, the width of the bed being not more than 60ft.

Cuttle Cove.—Very rich gold-bearing lumps of quartz have been discovered by two men recently prospecting in this locality, but they have not as yet found any solid lode from which the quartz is likely to have come. There is every chance of some good reefs being yet opened up in this locality.

Crayfish Island.—The gold found in the alluvial drifts has pieces of quartz attached; also, quartz stones have been picked up containing a fair amount of gold, with a result that several licensed holdings have been recently applied for.

About twelve months ago Mr. McAloney discovered two boulders of quartz, containing a large quantity of gold, in a little gully leading up from Preservation Inlet to the main range, about two miles from the Government oil-store. Four licensed holdings have been applied for, and the holders are said to have combined together to form a syndicate to carry on systematic prospecting operations, with the view of discovering the reef whence these boulders came.

In concluding my remarks on the West Coast Sounds, there is very little known about this part of the country. The whole of it is very rough and broken, covered with a dense tangled scrub, which renders walking through the bush a very slow and laborious undertaking. It is a portion of the colony which deserves attention in the matter of opening it up by roads and tracks. Land-communication should be established between Orepuki and this goldfield, and this would lead to some of the land being taken up for settlement purposes, and fresh diggings would be discovered. A road has been surveyed for about eight miles beyond Wilson River, and some of the creek-beds near the survey line are said to contain gold. Pack-horses can now be taken from Preservation Inlet to Wilson's River, but beyond this all supplies and provisions must be carried on men's backs, which is a work not appreciated by the rising generation.

BATTERY RETURNS FOR THE YEAR ENDED 31ST MARCH, 1894.

Battery.	Quantity crushed.	Amalgam.	Gold obtained.	
			Retorted.	Melted.
Nenthorn—	Tons.	Oz.	Oz.	Oz.
Week's machine, No. 44741	274	1,169	273	...
W. and G. Donaldson, No. 47836 ...	1,200	600	150	...
Bonanza Mine, No. 47834	125	...	114	...
Hindon—G. Lovel and party's machine ...	87	79	29	...
Barewood—Donald Reid	1,447	...	549	...
Serpentine — Serpentine Quartz-mining Company	75	...	...	68
Bald Hill Flat—				
R. J. Symes and party	57	93	40	...
Excelsior Gold-mine (F. W. Gray) ...	279	...	598	...
Cromwell — Cromwell Gold-mining Company (Limited)	571	1,056	354½	...
Macetown — Premier Consolidated Gold-mining Company (Limited), machine No. 384	3,163	...	...	1,985
Skipper's—				
Achilles Goldfields (Limited), machine No. 342	1,699	1,076	517	496
Leviathan Quartz-mine	15	...	...	24
Shotover—Gallant Tipperary Company ...	731	...	376	...
Totals	9,723	4,073	3,000½	2,573

The following statement will give approximately the returns from the quartz-mines in the colony for the past year :—

Name of District.	Number of Tons Quartz crushed and Tailings treated.	Yield of Gold.	Approximate Value.
	Tons.	Oz.	£ s. d.
Coromandel	12,630	10,019	
Thames	62,444	34,637	219,650 15 0
Ohinemuri	31,272	39,630	
Piako...	2,470	926	
Collingwood	4,561	914	3,610 0 0
Reefton	35,214	19,367½	77,470 0 0
Lyell	9,876	9,186	36,744 0 0
Otago	9,723	5,573½	22,015 0 0
Total	168,190	120,253	359,489 15 0

The following statement shows a list of the mining companies in actual operation on the 31st December last, as compiled from statements of affairs furnished by the managers of the companies, in accordance with the provisions of "The Mining Companies Act Amendment Act, 1890" :—

STATEMENT of AFFAIRS of MINING COMPANIES, as published in accordance with "The Mining Companies Act, 1886," and Amendment Act, 1890.

Name of Company.	Date of Registration.	Number of Shares.	Number of Shares allotted.	Nominal Capital.	Subscribed Capital.	Value of Scrip given to Shareholders.	Amount of Capital actually paid up.	Amount paid up per Share.	Number of Shares forfeited.	Arrears of Calls.	Amount of Dividends paid.
AUCKLAND DISTRICT.											
				£	£ s. d.	£ s. d.	£ s. d.	£ s. d.		£ s. d.	£ s. d.
Komata	23 April, 1892	20,000	15,056	20,000	20,000 0 0	..	..	..	..	..	..
Woodstock United	17 Feb., 1890	55,000	52,568	27,500	26,284 0 0	10,513 12 0	..	0 4 0	..	..	..
New Alburnia	10 Sept., 1885	50,000	49,663	25,000	25,000 0 0	2,500 0 0	3,625 0 0	0 1 9	..	..	7,949 9 0
Silverton	4 Feb., 1886	40,000	40,000	20,000	20,000 0 0	..	4,000 0 0	0 2 0	..	314 17 3	600 0 0
Norfolk	24 April, 1889	50,000	49,995	25,000	24,997 10 0	12,500 0 0	4,330 10 1	0 6 11	500	49 19 6	..
Lone Hand	22 Mar., 1889	50,000	31,700	25,000	15,850 0 0	500 0 0	1,467 19 2	0 1 0	..	30 18 9	..
Puhipuhi Prospectors'	18 July, 1890	53,360	52,025	26,680	26,014 0 0	10,005 0 0	7,755 4 8	0 7 2	150	514 1 8	..
May Queen	4 Mar., 1889	79,000	79,000	39,500	39,500 0 0	625 0 0	3,141 13 8	0 1 2	..	0 15 0	..
Red Mercury	22 April, 1890	30,000	30,000	7,500	7,500 0 0	937 10 0	3,937 10 0	0 3 3	1,505	..	..
Pride of Karaka	21 Oct., 1890	50,000	50,000	12,500	12,500 0 0	3,800 0 0	1,217 14 5	0 2 2	..	91 0 8	..
Mariposa	28 Feb., 1890	50,000	50,000	12,500	12,500 0 0	..	3,908 4 8	0 1 9	15,795	112 14 6	..
Occidental	2 Oct., 1890	100,000	53,700	25,000	13,425 0 0	..	..	0 0 1	..	0 16 8	..
Hazelbank	30 Sept., 1890	42,000	42,000	10,500	10,500 0 0	2,100 0 0	2,625 0 0	0 2 3	..	..	3,150 0 0
Magnolia	16 Feb., 1883	50,000	41,250	50,000	45,000 0 0	2,625 0 0	2,179 6 1	0 3 2	3,750	..	..
Victoria	2 Sept., 1890	120,000	117,183	24,000	23,823 18 9	10,472 18 0	7,113 15 0	0 1 10	64,551	268 19 3	..
Cambria	4 Jan., 1884	44,700	44,700	44,700	..	12,851 3 0	1,181 5 0	..	..	..	80,475 0 0
Waiotahi	1 Aug., 1871	6,000	6,000	18,000	18,000 0 0	..	15,000 0 0	2 10 0	..	..	29,250 0 0
City of Dunedin	6 May, 1890	50,000	46,550	25,000	23,275 0 0	11,637 10 0	1,391 19 7	0 5 8½	11,750	63 15 0	..
Calliope	8 Sept., 1890	50,000	50,000	12,500	12,500 0 0	..	1,250 0 0	0 0 6	50	88 4 7	..
Waihi	7 Dec., 1887	150,000	150,000	150,000	150,000 0 0	53,333 0 0	96,667 0 0	1 0 0	..	..	22,500 0 0
Otama	25 Mar., 1890	40,000	39,912	20,000	20,000 0 0	..	515 13 0	0 0 3	14,843	..	..
Junction	21 June, 1890	30,000	30,000	7,500	7,500 0 0	..	1,287 5 10	0 0 8	..	81 9 2	..
Orlando	2 April, 1890	40,000	40,000	10,000	10,000 0 0	..	2,829 3 4	0 1 5	200	..	184 3 4
North Star	21 Feb., 1891	50,000	45,000	10,000	9,000 0 0	3,375 0 0	1,425 0 0	0 1 6	10,000	41 13 4	..
Try Fluke	3 Dec., 1889	50,000	50,000	12,500	12,500 0 0	..	1,250 0 0	0 0 6	..	..	9,905 6 6
New Moanataiari	16 Nov., 1888	50,000	49,910	25,000	24,955 0 0	2,670 0 0	9,905 2 0	0 5 0	..	0 10 0	..
New Fearnought	22 July, 1886	50,000	50,000	25,000	25,000 0 0	..	1,856 9 9	0 1 0	..	105 19 7	..
Acme	2 Nov., 1893	50,000	39,050	5,000	5,000 0 0	850 0 0	367 10 0	0 0 4	..	..	..
St. Hippo	23 Feb., 1893	65,000	65,000	13,000	13,000 0 0	3,208 6 8	2,708 6 8	1/1 & 2/-	..	..	..
Maori Pah	17 Sept., 1890	42,000	42,000	10,500	10,500 0 0	..	..	..	..	..	..
Irene	26 Feb., 1891	50,000	36,000	12,500	9,000 0 0	..	372 10 0	0 0 3	..	69 3 4	..
New Zealand Crown Mines	19 May, 1891	100,000	77,729	100,000	77,729 0 0	..	27,728 5 0	1 0 0	..	..	2,791 2 0
Kapanga	30 Mar., 1872	250,000	249,756	250,000	249,756 0 0	..	..	0 3 0	240	223 17 5	4,625 0 0
Thames Lead and Silver Mining	22 Dec., 1892	155	155	5,425	5,425 0 0	..	1,500 0 0	15 0 0	..	109 1 5	..
Ophir Silver Mining	23 June, 1891	50,000	34,000	5,000	3,400 0 0	1,700 0 0	138 16 11	0 1 1¾	..	..	..
New Manukau	10 Feb., 1883	30,000	30,000	30,000	30,000 0 0	..	2,232 3 9	0 1 6	..	..	..
Freedom	18 Mar., 1890	24,000	24,000	6,000	6,000 0 0	..	900 0 0	0 0 9	..	89 7 6	..
Golden Age	10 Sept., 1890	25,000	24,200	6,250	6,050 0 0	..	156 5 0	0 0 1½	..	52 1 8	..
Totals	..	2,136,215	1,978,102	1,154,555	1,051,484 8 9	146,203 19 8	215,964 13 7	..	123,334	2,309 6 3	161,430 0 10

STATEMENT of AFFAIRS of MINING COMPANIES, as published in accordance with "The Mining Companies Act, 1886," and Amendment Act, 1890—*continued*.

Name of Company.	Date of Registration.	Number of Shares.	Number of Shares allotted.	Nominal Capital.	Subscribed Capital.	Value of Scrip given to Shareholders.	Amount of Capital actually paid up.	Amount paid up per Share.	Number of Shares forfeited.	Arrears of Calls.	Amount of Dividends paid.
NELSON DISTRICT (including West Coast).											
				£	£ s. d.	£ s. d.	£ s. d.	£ s. d.		£ s. d.	£ s. d.
A1	12 May, 1891	24,000	24,000	6,000	6,000 0 0	..	350 0 0	0 0 3½	..	39 11 8	..
Keep-it-Dark	2 Mar., 1874	20,000	20,000	20,000	20,000 0 0	10,000 0 0	4,625 0 0	0 4 7½	1,994	133 19 3	105,166 13 4
Globe	8 Aug., 1882	36,000	36,000	18,000	18,000 0 0	..	14,735 0 0	0 8 2½	5,450	..	40,050 0 0
Keep-it-Dark South, No. 2	13 June, 1887	24,000	24,000	12,000	12,000 0 0	..	6,800 0 0	0 5 8	..	245 11 3	8,600 0 0
Golden Treasure Extended	4 Dec., 1888	24,000	24,000	12,000	12,000 0 0	..	4,579 6 10	0 5 0	7,675	74 2 2	900 0 0
St. George	30 Oct., 1891	24,000	24,000	24,000	24,000 0 0	..	410 0 2	0 0 5	1,500	71 4 10	..
Durham	11 July, 1891	24,000	24,000	12,000	12,000 0 0	..	739 5 5	0 0 8	4,775	22 3 9	..
Cumberland	10 July, 1890	24,000	24,000	24,000	24,000 0 0	..	2,400 0 0	0 2 0	..	..	13,200 0 0
United Italy	24 Mar., 1882	24,000	24,000	24,000	24,000 0 0	12,000 0 0	4,150 0 0	0 3 5½	..	..	300 0 0
Inglewood Extended	25 Aug., 1882	24,000	24,000	12,000	12,000 0 0	..	8,550 0 0	0 7 1½	9,275	..	1,500 0 0
Alexander	15 Oct., 1890	24,000	24,000	9,000	5,250 0 0	..	3,160 0 0	0 7 6	..	165 0 0	..
Hercules	22 Nov., 1889	24,000	24,000	24,000	24,000 0 0	..	5,000 0 0	0 4 2	2,199	..	600 0 0
Progress	26 Nov., 1886	24,000	24,000	12,000	9,600 0 0	..	4,500 0 0	0 5 9	..	..	12,600 0 0
Lord Edward	13 Nov., 1883	24,000	24,000	24,000	12,000 0 0	12,000 0 0	2,550 0 0	0 12 1½	..	65 1 5	..
Big River	11 April, 1891	24,000	24,000	12,000	12,000 0 0	..	600 0 0	0 0 6	..	..	21,300 0 0
Sir Francis Drake	10 June, 1887	24,000	24,000	6,000	6,000 0 0	..	1,500 0 0	0 1 3	5,195	623 2 3	..
Golden Lead	30 Oct., 1890	24,000	24,000	12,000	12,000 0 0	..	4,500 0 0	0 3 9	3,950	..	..
United Alpine	31 Oct., 1874	32,000	32,000	48,000	40,933 6 8	16,000 0 0	24,933 6 8	0 15 7	..	..	69,866 13 4
Southern Cross	22 Mar., 1889	14,000	14,000	14,000	14,000 0 0	1,400 0 0	1,633 6 8	0 4 4	2,484	..	..
Johnston's United	27 June, 1881	20,000	20,000	20,000	18,584 11 6	1,668 0 0	12,409 5 11	0 15 11½	8,209	..	1,916 0 9
Wealth of Nations	21 Aug., 1889	32,500	32,500	32,500	21,125 0 0	..	21,125 0 0	0 13 0	..	..	..
Welcome United	4 Mar., 1893	48,000	48,000	24,000	..	..	2,427 17 0	0 1 3	14,371	237 19 9	..
Minerva	24 Feb., 1890	12,000	12,000	12,000	12,000 0 0	..	4,800 0 0	0 4 0	4,535	123 7 2	..
Sir Francis Drake Extended	30 June, 1893	24,000	24,000	6,000	6,000 0 0	..	1,500 0 0	0 1 3	5,195	623 2 3	..
Kumara Long Tunnel	16 May., 1882	16,000	..	16,000	8,000 0 0	..	7,433 6 8	0 9 3½	3,400	..	3,891 6 10
Duffer's Creek	1 Sept., 1891	24,000	24,000	9,000	..	4,000 0 0	2,600 0 0	0 5 6	..	..	..
Amazon	31 July, 1893	24,000	24,000	3,000	3,000 0 0	..	102 1 8	0 0 2	1,800	87 10 0	..
Nelson Creek	6 July, 1892	28,000	25,900	28,000	..	21,000 0 0	2,695 0 0	0 11 0	150	46 4 0	..
Wakamarina Gorge	7 Oct., 1892	15,000	30,000	30,000	15,000 0 0	15,000 0 0	1,500 0 0	0 2 0	14,150	176 17 6	..
Julian	17 June, 1893	24,000	24,000	9,000	..	..	..	..	..	20 6 3	..
Royal	2 June, 1888	24,000	24,000	24,000	13,850 0 0	12,000 0 0	1,837 10 0	0 11 6½	1,750	..	231 15 5
Success	13 July, 1891	24,000	24,000	12,000	12,000 0 0	..	284 11 8	0 0 4	3,975	75 18 9	..
Exchange Quartz-mining	23 May, 1890	24,000	24,000	6,000	6,000 0 0	..	2,450 15 6	0 2 1	2,900	2 15 0	..
Mont D'Or	25 July, 1882	12,000	12,000	12,000	12,000 0 0	..	10,799 14 0	0 18 0	..	..	21,000 0 0
South Pacific Extended	26 Oct., 1882	36,000	36,000	36,000	36,000 0 0	18,000 0 0	2,032 0 11	0 11 7	29,146	..	..
Humphrey's Gully	— May, 1883	150,000	144,000	150,000	67,000 0 0	77,000 0 0	62,984 0 0	0 19 0	4,016	..	..
Ross United	— May, 1883	150,000	150,000	150,000	46,500 0 0	103,500 0 0	45,350 12 6	0 19 6	701	..	..
Matakitaki Gold Dredging	7 July, 1892	2,000	2,000	2,000	2,000 0 0	..	773 11 0	0 10 0	..	62 19 0	..
Deep Creek Sluicing	12 Sept., 1893	4,177	8,177	6,000	2,085 0 0	1,000 0 0	420 4 0	0 2 6	..	..	..
Ravenscliff	23 June, 1890	60,000	38,290	60,000	38,290 0 0	59,608 0 0	16,909 0 0	1 0 0	..	63 0 0	..
Shamrock Lead	29 Sept., 1892	12,000	11,850	12,000	11,850 0 0	30 0 0	3,313 15 0	15/ on 3,390 13/ on 340 4/ on 2,270	670	306 9 10	..
Dillon	12 Oct., 1891	24,000	24,000	12,000	12,000 0 0	..	567 2 10	0 0 6	500	32 17 2	..
Davis and Carr's Terrace	13 Mar., 1890	2,000	1,385	2,000	864 15 0	864 15 0	242 0 0	0 17 0	460	46 0 0	644 0 0
Gallant	7 Feb., 1888	24,000	24,000	12,000	12,000 0 0	..	4,200 0 0	0 3 6	17,590	..	600 0 0
Venus Extended	21 Aug., 1885	24,000	24,000	24,000	24,000 0 0	..	4,159 0 0	0 3 8	6,950	241 0 0	2,700 0 0

STATEMENT of AFFAIRS of MINING COMPANIES, as published in accordance with "The Mining Companies Act, 1886," and Amendment Act, 1890—*continued.*

Name of Company.	Date of Registration.	Number of Shares.	Number of Shares allotted.	Nominal Capital.	Subscribed Capital.	Value of Scrip given to Shareholders.	Amount of Capital actually paid up.	Amount paid up per Share.	Number of Shares forfeited.	Arrears of Calls.	Amount of Dividends paid.
NELSON DISTRICT (including West Coast)—*continued.*											
				£	£ s. d.	£ s. d.	£ s. d.	£ s. d.		£ s. d.	£ s. d.
Specimen Hill	13 Feb., 1893	20,000	20,000	10,000	10,000 0 0	..	497 13 2	0 0 8	11,836	24 3 6	..
Sir Charles Russell	16 Oct., 1890	24,000	24,000	12,000	12,000 0 0	..	3,262 3 11	0 2 10	..	137 16 1	..
Star Antimony	16 May, 1892	10,000	10,000	10,000	10,000 0 0	..	2,485 15 1	0 5 6	..	264 4 11	..
Greenstone Sluicing	8 Dec., 1888	7,000	7,000	7,000	7,000 0 0	2,300 0 0	2,702 10 0	0 11 6	..	..	1,750 0 0
Lyell Creek Extended	2 Aug., 1881	48,000	48,000	24,000	12,000 0 0	12,000 0 0	..	0 4 6	..	..	..
Totals	..	1,410,677	1,382,102	1,097,500	739,932 18 2	379,370 15 0	317,579 16 7	..	176,751	4,011 17 9	306,816 8 8
OTAGO DISTRICT.											
Hesperides	11 Oct., 1893	6,000	6,000	6,000	6,000 0 0	3,000 0 0	126 11 2	0 0 6	..	23 8 10	..
Bluespur and Gabriel's Gully	1 Feb., 1888	130,000	90,000	130,000	90,000 0 0	30,000 0 0	30,000 0 0	1 0 0	..	..	..
Longwood Sluicing	15 Oct., 1888	400	321⅜	4,000	3,032 0 0	2,912 0 0	2,912 0 0	£2 to £10	..	43 0 0	..
Rise and Shine	22 July, 1890	10,000	10,000	3,000	3,000 0 0	1,500 0 0	1,440 15 0	0 6 0	340	59 5 0	..
Amalgamated Waipori Deep Lead	20 Dec., 1889	12,500	12,050	12,500	12,050 0 0	6,150 0 0	5,823 1 0	1 0 0	..	76 19 0	..
Roxburgh Amalgamated Sluicing	2 Mar., 1889	30,000	29,152	30,000	29,152 10 0	15,000 0 0	12,737 5 0	0 18 0	412	6 14 4	1,822 0 0
Sew Hoy, Big Beach	9 Dec., 1889	54,000	54,000	108,000	108,000 0 0	72,000 0 0	8,771 18 9	1 10 0	225	3 1 3	10,088 8 9
Jutland Flat (Waipori)	2 July, 1890	15,000	15,000	15,000	15,000 0 0	3,750 0 0	4,000 0 0	0 8 0	..	..	1,875 0 0
Sandhills	2 Aug., 1889	25,000	25,000	12,500	12,500 0 0	4,000 0 0	7,142 4 0	0 10 0	200	80 0 0	849 18 10
Cromwell	16 Nov., 1889	110,000	108,021	110,000	108,021 0 0	97,218 18 0	8,499 1 0	0 19 10½	3,417	288 1 1½	..
United Hercules	13 Aug., 1888	12,000	12,000	12,000	12,000 0 0	4,125 0 0	4,125 0 0	0 15 0	..	..	8,400 0 0
Undaunted	— Mar., 1878	120	120	9,600	9,600 0 0	..	9,600 0 0	Full.	..	..	..
Premier Consolidated	8 Nov., 1890	30,000	30,000	70,000	30,000 0 0	40,000 0 0	30,000 0 0	1 0 0	..	..	..
Tipperary	10 Mar., 1891	35,000	35,000	35,000	35,000 0 0	..	5,000 0 0	18/6–19/6	..	..	..
*Achilles Goldfields (Limited)	6 July, 1893	100,000	..	..	..	..	..	..	..	..	..
Bonanza	16 July, 1890	12,000	12,000	12,000	10,486 0 0	9,000 0 0	1,448 10 0	0 2 3⅝	..	37 10 0	2,732 8 0
New El Dorado Sluicing	17 April, 1893	2,000	1,911	2,000	1,911 0 0	1,911 0 0	341 0 0	1 0 0	..	150 0 0	..
Totals	..	584,020	440,575⅜	571,600	485,752 10 0	290,566 18 0	131,967 5 11	..	4,594	767 19 6½	25,767 15 7
DREDGING COMPANIES (Otago District).											
Upper Waipori	3 Sept., 1889	24,000	24,000	12,000	12,000 0 0	5,000 0 0	5,950 0 0	0 8 6	..	..	2,400 0 0
Edina	10 July, 1893	5,000	5,000	2,500	2,500 0 0	600 0 0	1,072 10 0	0 6 0	..	33 15 0	..
Island Block	28 Nov., 1888	56,917	56,917	60,000	21,917 0 0	35,000 0 0	21,917 0 0	1 0 0	100	..	..
*Roundhill Mining	21 July, 1892	..	..	..	..	..	..	..	..	..	..
Miller's Creek	11 June, 1890	10,000	10,000	10,000	10,000 0 0	4,000 0 0	5,100 0 0	0 17 0	100	222 10 0	..
Roxburgh Gold	20 Aug., 1891	5,000	5,000	5,000	2,500 0 0	2,500 0 0	1,988 10 0	0 16 0	..	11 10 0	1,000 0 0
Golden Run	29 June, 1891	5,000	5,000	5,000	3,000 0 0	2,000 0 0	2,218 5 0	0 19 0	1,085	..	2,446 17 6
Ettrick Gold	29 Aug., 1890	4,500	4,500	4,500	2,500 0 0	2,000 0 0	1,873 0 0	0 15 0	..	2 0 0	..
Dunedin	1 Sept., 1881	8,700	8,700	8,700	8,700 0 0	..	7,540 0 0	0 17 4	..	..	13,530 0 0
Six-mile Beach	19 Oct., 1889	12,000	12,000	12,000	12,000 0 0	2,250 0 0	7,449 0 0	0 17 6	..	51 0 0	..
Enterprise	24 Aug., 1891	2,200	800	2,200	800 0 0	800 0 0	800 0 0	1 0 0	..	..	..
Phœnix Water-race	12 Oct., 1867	1,000	1,000	1,500	1,500 0 0	1,500 0 0	1,500 0 0	1 10 0	..	..	5,550 10 0
Totals	..	134,317	132,917	123,400	77,417 0 0	55,650 0 0	57,408 5 0	..	1,285	320 15 0	24,927 7 6

* Particulars not received from Liverpool, where the head office of the company is situated.

ALLUVIAL MINING.

MIDDLE ISLAND.

The principal portion of the gold is still obtained from the alluvial drifts of the Middle Island. According to the battery returns, taking the value of the gold obtained in the North Island against the value of that got from the quartz workings in the Middle Island, it would show that about 90,000oz. gold, worth about £4 an ounce, was obtained from quartz workings, and 150,702oz. gold was obtained from the alluvial workings; so that it may be said that about 37½ per cent. of the gold obtained comes from quartz lodes, and 62½ per cent. from the alluvial drifts. There is no doubt but what the richest portions of the alluvial drifts in shallow ground have been worked; but there are still large areas of auriferous drifts on the West Coast and in Otago which the next generation will not see exhausted. And there is no reason to suppose that the richest portions of all the alluvial drifts have been worked. There is plenty of deep ground, both on the West Coast and Otago, where very rich auriferous beds of wash-drift are known to exist; but the difficulty to cope with is so great that men with small means cannot undertake to carry on the extensive operations required to bring these mining ventures to a successful issue.

The improved appliances and methods of working these alluvial drifts enable ground which a few years ago was considered totally valueless to be dealt with at a profit; indeed, it becomes a question as to the actual quantity of gold required in the ground to make it payable for working, as this depends to a large extent on the quantity of water that can be taken on to the ground to work it. Notwithstanding the large supply of water there is in the colony, if the whole of the rivers and streams within the boundaries of the goldfields could be lifted and made to flow on the high lands, these could be profitably utilised. It is only a question of time when every available site will be taken up on the goldfields for the conservation of water. The recent explorations of Mr. A. McKay, the Mining Geologist, show that the area of the auriferous quartz drifts in Otago is very large. To commence in north-eastern portion of Otago, these drifts extend for fifty miles up the Waitaki to Shag Point. On the opposite side of the Kakanui Mountains they are present in many places round the borders of the Maniototo Plains. Hyde, Hamilton, and Sowburn have notable diggings in these drifts. Clarke's, on the top of Mount Buster, is also of the same material; and from the foot of this mountain they extend along the northern margins of the Maniototo Plains to the Wether-burn; thence along the foot of the Hawkdun Mountains to near the head of the Mount Ida Water-race. A line of these quartz drifts completely encircles Idaburn and Poolburn Valley, German Hill, Black's No. 3, Woolshed, and Hill's Creek being gold-workings in this material. From the foot of the gorge of the Manuherikia another line runs south and west to Blackstone Hill Station at the crossing of Manuherikia River, Pennyweight and Pipeclay Gullies being the principal workings on this line.

On the opposite side of the Manuherikia River, from Blackstone Station, a line of these drifts extends to the north-west side of Muddy Creek, from the crossing of the road to St. Bathan's to beyond the Scandinavian Claim. The same drifts are largely developed in the St. Bathan's basin, which, although apparently isolated, it will probably be found that a connection with this basin will be traced in a horse-shoe bend to Vinegar Hill. From Vinegar Hill a long line of these drifts extends along the foot of the Dunstan Mountains to Clyde. The drifts on this line are usually found standing at a very high angle, and the more auriferous portions are usually in near contact with the slate rocks, which renders the working of them at all times difficult, and sometimes dangerous. The gold-bearing strata shows no diminution in the quantity of gold it contains to the greatest depth that has yet been prospected, and it is a question as to what depth this material can be profitably worked. Vinegar Hill, Cambrian's, Dry Bread, and Tinker's are the most important places along this line.

Recent prospecting in Waikerikeri Creek shows also that here will be an important place for working these drifts. On the opposite side of the Manuherikia Valley, from Chatto Creek to Alexandra, there is another line of quartz drift, which, to the south-west, corresponds with that along Butcher's Gully and Bald Hill Flat, and having a parallel but independent line running along Conroy's Gully. In Butcher's and Conroy's Gullies these drifts have evidently yielded gold to the more modern wash in the creek-beds.

In following the Molyneux River downwards, quartz drifts are found from Noisy Creek to Coa Creek. At the mouth of the latter creek this drift shows on the banks of the Molyneux River, and may have yielded gold to the gravels in this vicinity. Throughout the basin of Moa and Miller's Flats quartz drifts are not seen at the surface, but lignite is exposed on the bank of the river at Ettrick, and on the Miller's Flat side there are large numbers of white stones, which indicate the presence of the quartz drifts at no great distance.

There are no more quartz drifts to be found near the river until the junction of the Pomahaka, where, over the Burning Plains south of the Tapanui Mountains, there is a large area of quartz drift which is known to be auriferous, but there are no important diggings on this area. From the Beaumont, on the road to Lawrence, about a mile before crossing into the Tuapeka watershed, there is an area of quartz drift forming a hill and filling the valley on the west side of the road. This is reported to be auriferous, but it has not been sufficiently prospected. Similar areas of greater or less extent occur on the high land towards the mouth of the Tuapeka river, at Munro's Farm, Evans's Flat, and Lawrence racecourse. These drifts are said to be gold-bearing.

At Coghill's Hill, opposite Waitahuna Railway Station, there is fully 20ft of quartz drift, covering an area of about 2 acres. The upper part is hard cement; the lower part, about 12ft. thick, is of loose quartz sand, which was at one time considered sufficiently rich in gold to pay for carting to the Waitahuna River. Could water be brought to command this ground it would pay very well for working. This, however, is impossible, as the hill is higher than the surrounding country for some distance.

To the east of Coghill's is Sutherland's Hill, where there is a considerably larger area of quartz drift. Here also the upper portion is cemented, and the lower portion loose drift. This place has not been prospected, but it is quite as likely to contain gold as Coghill's Hill. Water could be brought on to some parts of the ground.

On the east side of Waitahuna Gully there are several patches of quartz drift, known to be auriferous. The available water that would command this ground is utilised in Waitahuna Gully in connection with the breccia deposit, similar to the material worked at the Blue Spur.

At Manuka Hill—Coomb's claim—there is a small area of quartz drift which paid very well for working. Conditions were the same as at Coghill's Hill; and the material had to be taken down the hill to the west branch of Tokomairiro River to be washed. South of this, and west of Glenore Railway-station, considerable areas of this drift rest on the top of the hills. The dip of the beds being south, they pass under the coal-measures at Lovell's Flat, and extend along the foot of the hills to Stony Creek, and show in many places in the railway-cuttings between Lovell's Flat and Stirling. Quartz drifts are developed to a large extent over the area of the Kaitangata Coalfield, and they are well exposed in section on the coast-line, near Coal Point, where they are said to be gold-bearing. The same material is also exposed in Fraser's Creek, which discharges into the Kaitangata Lake. The drifts here frequently alternate with beds of slaty breccia, the same as at the Blue Spur.

At Green Island, Saddle Hill, and Silver Stream there are large areas of quartz drifts which have not yet been prospected. Also, there is a large area of the same material to the north of Waikouaiti, within the watershed of Pleasant River, on Hummock side, west of the Stoneburn, and within the valleys of Moonlight, Nenthorn, and Deepdell Creeks, and on the slope of the Taieri Ridge to Strath Taieri. There are, or have been, rich workings in these beds at Macrae's, Horse Flat, Station Hill, Fullarton, and the Mareburn.

Between Tapanui River and the Mataura River, and from the railway-line to the Waikaka Diggings, there is a large area of the quartz-drift, within which is situate the Waikaka and McKenzie Diggings, and many small areas of this material have been worked on Knapdale Run. Gold was first discovered in this district by Gabriel Reid, at Land-slip Hill, in 1862. The wash-drift at Waikaka is somewhat peculiar. There is a total absence of rough rubble and creek-shingle, the wash consisting purely of quartz pebbles and sand, which on the terraces is covered by a variable depth of loam. The surface-wash rests on the upturned edges of the older quartz-drift, some bands of which are highly auriferous. A shaft was sunk at the back of the Waikaka Township n one of these quartz-drift lands to a depth of 120ft., following a particular stratum to that depth. The amount of gold obtained does not seem to have been sufficient to pay for working, as the work has been suspended. It is a field for hydraulic sluicing, and is not ground that can be worked by driving it out.

The principal gold-bearing area at Switzer's lies on the east side of the valley. The northern part exposes the quartz drift, the eastern and southern parts being principally "Maori bottom," or what is termed "Old-man Reef," from beneath which the quartz drift appears in the south-west part of the area. The largest quantity of gold found at Switzer's has been got on the "Maori bottom," but three or four claims are working on the quartz drift on the southern part of the field. On the northern part several claims have been worked in this drift, but they are now abandoned. On the west side of the river—Muddy Creek—the modern drifts are a mixture of rough shingle and quartz drift, constituting shallow workings, resting on a slate bottom. At Muddy Creek these drifts are worked as well as other workings on the "Maori bottom."

At the Nevis the quartz-drift is present on both sides of the valley. Near the township the beds are vertical, and somewhat resemble the Blue Spur deposits. More to the north the beds are pure quartz grit, and are continued in a narrow line deeply involved between the older rocks in a line across the hill to Gibbston, and again appear as a small patch on the opposite side of the river, near the Cardrona Saddle, and again at Mr. McDougal's coal-mine at the Upper Cardrona.

At Bannockburn the quartz drift is largely obscured by the "mountain-wash." It shows however, at the surface near Angel's Hotel, in the upper township, and formed the bottom o many of the large sluicing-claims. The grit-beds, being nearly vertical, are promising in character, but have not been prospected. This line runs along the foot of the Carrick Range to the Kawarau Station, and thence into the Upper Bannockburn. On the east side of the Lower Bannockburn there is also a large development of this drift. North-east of the Kawarau Gorge this line of drift should be continued along the foot of the Mount Pisa Range, but heavy gravel terraces of more recent date overlies and obscures it, the gold-workings at Lowburn and other creeks being probably supplied with gold from the gravels of more modern date.

The older workings on the north side of Luggate Creek and Criffel were in some parts very rich, but the area of the quartz drift here is of limited extent, and is nearly worked out. The more extensive deposit known as "Fat Boy" lies on the south eastern side of the Luggate, and extends south-east and north-west for about four miles of a variable width of from 4 to 15 chains. On the western side the drift is faulted downwards against a schist rock, and on that side the ground is deep. Naumann and party, who hold the northern portion of this line, have been engaged in prospecting the ground for the past two years, but so far have not met with great success.

A line of deeply-involved gold-bearing strata runs along the middle part of Criffel Face from Mount Barker to opposite the Cardrona Township. This line appears to be auriferous throughout, as it is being worked at Mount Barker, and has been proved auriferous in the middle part, and again being worked opposite Cardrona Township.

Another long line of quartz drift extends from Bob's Cove, on the northern shore of Lake Wakatipu, across Moke Creek, Moonlight Creek, Stony Creek, and Skipper's, to the eastern slopes of Mount Aurum. Along this line the quartz grits are usually indurated into a hard rock; they are not, therefore, likely to pay for working for the gold they contain.

Mr. McKay, in his last year's explorations, has, in tracing these auriferous quartz drifts and gold-bearing breccias in Otago, shown that there is a large field for the extension of gold-mining in the alluvial deposits, but the whole of the areas mentioned require to be worked by hydraulic sluicing to make them pay, and this naturally comes to the question of utilising the whole of the available creeks and streams—the construction of dams and reservoirs for the storage of water, so that none of it be wasted. On the West Coast goldfields extensive auriferous gravel deposits exist, which are capable of giving profitable employment to a large population if water were available.

Marlborough District.

Mahakipawa.

The mining population here is gradually getting less, the best portion of the creek claims on Crown lands having been worked out. There are still a great many solid blocks of ground, the taking-out of which will afford employment to men for a considerable time, and if the water in the creek-bed was diverted, there is no doubt but that a great portion of the ground would be worked over a second time. During the last year the repeated floods in the creek have prevented mining operations from being carried on for more than half the time. The slightest flood in the creek very soon fills all the underground workings with water, and, as the pumping appliances are all very small, it takes weeks before the ground is again drained so as to allow the men to work.

Arrangements have been made to put a dam across the creek-bed, where the bed-rock is near the surface, and to place a flume alongside the terrace to carry the water in ordinary flood-time. When this flume is completed it will enable the men to work the ground more steadily.

The Hibernian Company went into liquidation last year, and the property was purchased by Mr. Darrell, who is now carrying on mining operations.

The King Solomon Company has been able to work this year more regularly than during the previous one on account of having puddled back the water in the shaft at about 40ft. below the surface, where an impervious stratum was found. This has been the means of effectually damming back the surface-water, and the result has been that the workings have been carried on at a profit. There is yet some distance of the lead of auriferous wash drift to work on the upper end of the ground adjoining the Hibernian Claim, and there is about 60ft. between the workings and the Empire City Claim, adjoining the lower boundary.

Judging from an examination of the surface of the ground and surroundings, there is every indication of the course of the Mahakipawa Creek having been close against the foot of the range at the back of the township, and that, after having had its course there for a long period, a slip from the side of the range has taken place, which blocked up the original course of the creek, causing the water to cut its present channel on the opposite side of the valley. The remains of the slip are clearly seen, and a portion of the Township of Cullensville is built upon it. The inference to be taken from this is that the auriferous lead of wash drift will be found passing through the Empire City ground, and under Mr. Matheson's hotel, and thence along the foot of the range. If prospecting were done in this direction it is likely to be accompanied with success.

The Golden Gate and Alice Fell Companies, who hold claims lower down the flat than the township, have never been in the runs of auriferous wash drift that came down the old creek-bed. Whatever gold was got in these claims came from the run that is being worked by hydraulic sluicing on Davis and Carr's claim. It is probable that the original creek-bed will be about from 3 chains to 6 chains nearer the range than the last shaft put down by the Alice Fell Company.

Davis and Carr's claim is still continuing to give fair returns. There is a considerable depth of wash drift on the terrace where they are sluicing, and indications point to its being a portion of an old slip from the side of the range, and in this case there is a probability of wash drift being found higher up the range that will prove payable for working, but the difficulty would then be the getting of a supply of water. When once the creek-bed is all worked out, water can be lifted from the Mahakipawa Creek and its branches in order to sluice the ground on the side of the terrace, but at the present time this would be impracticable on account of the number of men who hold claims in the creek-bed. A good deal of gold has been taken from this field, and it is still a field that will afford employment to a small mining population for many years, and if the gold can be traced down the flat it would give the field a new life; nevertheless, if such were the case, much more powerful pumping plants would have to be used, so as to successfully contend with the water.

Wakamarina.

There are only a few parties working in the valley of the Wakamarina. The bed of the river in the early days had rich deposits of auriferous wash drift, and in some of the bars and crevices in the rock in the river-bed the clean gold could be taken up the same as out of a sluice-box. Some of the tributaries of the river, such as Deep Creek and Dead Horse Creek, were very rich for a certain distance up from their junction with the river, but above the line of reefs there was very little gold found. Deep Creek was especially very rich near its junction with the river, and directly below its junction there is a deep, narrow gorge which has never been worked, and a good many people have still a belief that heavy deposits of gold exist there. About eight years ago a company was formed to work this gorge, but the capital was too small to even get a dam put in and the water pumped out. This company has been re-formed at least three successive times, expending all its capital, and very little more is known about the deposit in this gorge than when operations were first commenced. Altogether, about £10,000 has been expended. A great deal of this money was frittered away in dilly-dallying while taking out the wash drift after the water was pumped out. It is one of those places where all the hands that could be profitably employed should have been put on, so as to take the ground out quickly, the river being very liable to sudden freshes, and all the work done would thus to a certain extent be destroyed.

Nelson District.

Collingwood.

There is a considerable number of miners in the Collingwood district, but they are greatly scattered about in the different gullies. There are very few working in any one place. The great difficulty the miners have to contend with in this district is the lack of an ample supply of water, and their present system of working has so long been adhered to that it may be said that many of the miners do not sufficiently understand the importance of using a large supply of water; they are quite content to catch a supply in a small dam, and, when this is full, to use the water sparingly. There is, apparently, a large area covered with a great depth of auriferous quartz drift in the quartz ranges, where several miners are making a livelihood, working the ground with small driblets of water. Some of those who had been working in this locality informed me that there are many places where gold can be found in the drift from top to bottom; and, if this be so, steps should be taken to bring a good supply of water on to this ground. One of the finest sites in the district for the construction of a large reservoir at comparatively little expense, is at Boulder Lake, by damming up the outlet, which is a very narrow, rocky gorge. From the reservoir thus formed water could be brought at a great elevation to command the whole of the ground in the quartz ranges.

The only mining operation of any magnitude that is being carried on in the district is that of the Parapara Hydraulic-sluicing Company. They hold the whole of the water-rights from the Parapara River, and are engaged in the construction of a tunnel to lift the water at the gorge, and to bring it in an open conduit and pipes from the end of the tunnel, to work the ground in Appo's Flat, Glengyle Gully, and Mr. Travers's freehold on Parapara Flat. The cost of the works and plant is estimated at £20,000.

The headworks consist of a concrete weir across the upper end of the gorge of the Parapara River, which will enable the water to be taken for a few chains from the river in an open conduit to a tunnel which is now in course of construction. This tunnel will be about 24 chains long, and will convey the water from the Parapara watershed into the watershed of the Aorere River, and it can be taken over the Glengyle Saddle and across the Parapara River to work the special claim the company has on the Parapara Flat and Mr. Travers's freehold. From the lower end of the tunnel the water will be carried for some distance in an open conduit, and thence in wrought-iron pipes. The intention is to commence the work at some freehold ground the company has purchased from Mr. West in Appo's Flat. About 12 chains of the tunnel is already constructed, and a contract for the construction of the iron pipes has been let to Mr. Sparrow, of Dunedin.

It is doubtful, from the information supplied me when in this district, whether there will be a large extent of ground that the company can work in Appo's Flat without constructing a long tail-race. The ground will have to be worked by hydraulic elevators, and it is said that the lower end of this flat is over 100ft. in depth, which means that three lifts would have to be used to bottom this ground; and if the gold be confined to a stratum of wash drift on the bottom, the large quantity of the upper gravel to be lifted, should there not be a little gold through it, will make the average yield per cubic yard very small unless the bottom layer be very rich; and even in this case it would become a question whether it would not be more economical to pump the water with the elevators, and drive out the bottom layer, if the gold is entirely confined to it. On the other hand, if the company commenced to work the upper portion of the flat, that could be lifted by one elevator, the tailings would have to be deposited on the lower ground, and this would increase the expense of working it on the elevating principle at a future date.

So far as the works have progressed, everything has been substantially constructed; but it is questionable if their capital will be sufficient to carry out the whole of the scheme and commence operations on Mr. Travers's freehold. There is an abundant supply of water in the Parapara River, and with this any poor ground can be made to pay for working. My impression is that the richness of the ground has been greatly over estimated; still, the ground should be sufficiently good to give a fair return for the outlay with the plant that is being constructed, and by working it systematically, with strict economy. At the time of my visit to the district rumours were afloat that the tunnel was likely to go through very bad swelling ground, but, after a careful inspection, my idea in regard to this is that it is probable that care will have to be exercised when going through a slide which cuts through the line of tunnel; but beyond this there is nothing to fear. Double sets of timber had to be placed for a short distance of the portion constructed at the time of my visit, but there was no sign at that time of any undue pressure being on the timber.

Matakitaki.

There are about twenty European miners, besides several Chinese, working up the Matakitika River, and the terraces about Glenroy. This place is little known, but, from the information given me when in this locality, the miners are doing better than in many of the other fields. There are very few who do not make wages when they work. At the upper end of the Horse Terrace, Mr. White, an old miner in the district, has brought in a water-race from a small creek, and opened out a claim in the face of the terrace facing the Matakitaki River. He has a supply, in ordinary weather, of about two or three sluice-heads of water, and the face he is working is about 100ft. high. The gravel, on the top is of loose fine drift, but about half-way down there is a good-looking wash drift; and he informed me that this claim was paying him very well for working. The gold he obtains is greatly rounded and beaten up, the same as though it had been carried some distance by a stream, and ground up amongst the boulders. Nevertheless, the sample he showed me was of good quality, and, judging from the quantity he is getting, his claim must pay him very well for working.

On the opposite side of the river from White's claim there is a small flat, in which a large number of holes have been put down, and the ground near this side of the river has been all

partially worked. On the northern side of this small flat a special claim of 100 acres has been taken up, and Mr. White informed me that, so far as he had prospected the ground, it was better than the claim he was working. Since my visit to this locality Mr. Proust has been sinking shafts on this terrace, and washing the material that came out of them, with the view of determining the average quantity of gold there is in the drift, and he is fully satisfied with the results. Indeed, the situation of this ground is such that a large stream of water can be brought from the Matakitaki River at a comparatively small cost, and the outlet for tailings is all that can be desired. The whole of the terrace can be sluiced in the ordinary manner, without any trouble about fall for tailings.

Taking the average of the washings from the shaft that Mr. Proust sank, he states that it is over $3\frac{3}{4}$gr. of gold to the cubic yard of material, and with this quantity of gold in the ground, and the facilities there are for working it, there are few places in the colony where such a claim can be found. One thing is certain, there has been a large quantity of gold obtained in the bed of the Matakitaki River between this place and Murchison, and it must have come from the washing-away of the terraces in this locality. When one comes to see this place, and learn of the amount of gold that has been got from time to time, it is really a wonder that more men have not been mining in this district.

WEST COAST.

Westport District.

The principal gold-mining operations in this district are carried on by hydraulic sluicing. A few men are employed on the ocean-beach between Westport and Ngakawau, working the auriferous black sand which is thrown up at times by the action of the waves; but the most of the miners in the district are working on Bradshaw's Terrace and the leads on Addison's Flat. There seems to be a large area of auriferous drifts on this flat, and a number of different leads of gold. At one time the land was at a much lower level than it is at present, and the sea has washed in close to the foot of the ranges, as all the gold that is now obtained on Addison's Flat is from leads formed by the action of the ocean-waves. It is extremely fine, and difficult to save, and it is only by the use of wide tables covered with blankets or cocoanut matting, having the cloths regularly washed out, and the sand amalgamated, that a fair percentage of the gold in the wash drift is obtained. Some of the miners have been working on this Flat since it was opened about thirty years ago, and the most of them have done very well; but water is the great adjunct to working the ground, whether by sluicing into a tail-race and hauling up the tailings by a water-balance, or using hydraulic elevators. A good supply of water is requisite to make the ground pay for working. The majority of the old miners use a water-balance, and have great objection to hydraulic elevating as being an innovation on the long-established system of working the ground, but this will soon wear off when once it can be shown that the ground can be successfully worked by this method.

There is no doubt a deal of poor ground on this Flat, as in many other places where large areas of auriferous gravel exist, but, with improved appliances for working, there is a large field here where miners can make small wages. All the water that can easily be brought on to the ground is taken up and conserved in numerous reservoirs in different places on the Flat; therefore the number of men that can be profitably employed on this field is limited to the supply of water. The ground is not sufficiently rich to pay for sinking and driving out. It is only those who have command of a good supply of water who can carry on mining operations advantageously.

The same character of ground extends to Croninville and Charleston to the southward, and to the Wareatea Creek and Fairdown to the northward. A prospecting association in Westport has started a tail-race from the ocean-beach, and intend to carry it through the swamp and under the railway with a tunnel, in order to try and cut any sea-beach lead that may exist between Fairdown and the sea; and there is a very probable prospect of this venture proving a success. If leads of gold were found parallel to the ocean-beach in this swamp it would be the means of creating profitable employment for a large number of miners.

Shamrock Company.—This company has constructed a water-race from the Totara River for a distance of four miles, and is now working the ground on the Shamrock lead by hydraulic elevating. This ground was driven out in the early days, and it was stated that it became so deep and wet that it could not be worked further, and that very rich auriferous wash-drift was left in the lead when the workings were abandoned. The present company was formed for the purpose of working this deep ground; and after completing the construction of the water-race, about 1,000ft. of iron piping was sufficient to take the water from the end of the water-race to the claim, and give 330ft. of head at the surface. The water-race, which has a carrying-capacity of twenty-two sluice-heads of water, terminates on the top of a flat terrace directly above the claim, and from the terminating-point the water is conveyed in iron pipes 17in. in diameter, having branch supply-pipes of 15in. and 11in. diameter respectively. The elevating-pipes are 15in. in diameter, with an 8in. throat-piece, the nozzle being 3in. in diameter and the sluicing-nozzle $2\frac{1}{4}$in. diameter, which have a discharge of 6·9 sluice-heads and 3·9 sluice-heads respectively; and the height that the material is lifted is about 54ft. Therefore, the elevator has to lift 6·9 + 3·9 sluice-heads of water, exclusive of material, to a height of 54ft.; but, in addition to this, the drainage of the ground will equal about one sluice-head of water, so that the total quantity of water lifted would be 11·8 sluice-heads.

Taking the hydrostatic heads in the bottom of the paddock, which is 38ft. below the surface, to be equal to 350ft., the ratio of power used would be $\frac{6{\cdot}9 \times 350}{11{\cdot}8 \times 54} = 3{\cdot}79$. This means that the ratio of power used to work these elevators effectively is 3·79 times the power required to lift the water, exclusive of any material. The weight of the material is but a small consideration in comparison to the weight of water, and would only form a very small element in the calculation. The work done seems to bear a favourable comparison with the work done by hydraulic elevators in Otago.

The material is lifted into a sluice 3ft. in width, which has at the end a false bottom of perforated iron plates, having holes half an inch in diameter in the upper plates and $\frac{3}{8}$in. diameter in the lower plates. The fine material goes over a set of tables 100ft. in width and 17ft. in length, and the coarse gravel and stones go over the perforated plates, and are then dumped on the tailings-heap. The gold is very fine, and of the same character as that found on the sea-beach, and requires the same process to be adopted for saving it. When the company first commenced sluicing operations there was only 50ft. in width of tables; but it was found that this was not sufficient for the quantity of material that was passing over them, and an additional width of 50ft. was therefore added, which now seems to work very well. The whole of the plant was erected by Mr. Réné Proust, Mining Engineer, who has now been for the last five years engaged in the erection and working of plants of this description, and is therefore fully conversant with all the details. The plant at the Shamrock has been well constructed, and reflects the highest credit on Mr. Proust.

At the time of my visit to this claim in May last a large paddock had been taken out, and the manager, Mr. McGregor, afforded all information as to the quantity of gold that had been extracted. The hydraulic operation commenced on the 5th of February last, and up to the date of my visit, on 19th May last, about 1,124oz. of amalgam had been obtained, which, the manager stated, went about 1oz. retorted gold to every 4oz. amalgam. This would give about 281oz. gold, which would represent a value of about £1,096. Judging from the area of ground that had been worked it would not exceed 100 yards long by 33 yards wide and 10 yards deep. This would give about 33,000 cubic yards. The average yield of gold would be, therefore, about 3·36gr. to the cubic yard of material lifted. Although the actual number of working-days between the dates mentioned was seventy-four, on fifty-seven of these only were sluicing operations carried out, according to the daily return of amalgam, which was taken from the manager's book; and for a portion of this time there was only one shift of men employed. At the time of my visit there were fifteen men employed in connection with the head-race tables and stone-trucks and sluicing operations. Allowing that even this number of men had been employed for the whole of the time at an average wage of 10s. per day, this would only amount to £555, which would still leave £541 for material and interest on capital. It is also well known that there is always more expense in connection with opening out the first paddock than afterwards. This venture, with careful management, should prove a very good investment for those interested in it.

Cement Workings.—There are considerable areas on Addison's Flat and Charleston where the auriferous sand is so tightly cemented together with oxide of iron that it cannot be broken up in the ordinary process of sluicing sufficiently fine to liberate the gold it contains. This cemented sand has to be pounded up by small crushing batteries before the gold can be obtained. The following are the returns from the cement-crushing batteries for the year ending 31st March last:—

Name of Party and Locality.	Number of Tons crushed.	Yield of Amalgam.	Yield of Gold.	Value of Gold obtained.
		Oz.	Oz.	£
Addison's Flat—Venture Company	8,372	2,297	664	2,590
Charleston—				
P. Higgins	3,287	253	65	254
Dwyer and party	867	Not given.	92	359
William Fox	2,800	Not given.	52	203
James Birch	1,300	Not given.	45	176
Mullins and party	3,240	170	58½	318
Dublin City Company	1,750	540	139	545
Parsons, Woodhead, and party	1,100	350	114	445
Totals	22,416	...	1,229½	4,890

At Charleston there are a few parties carrying on sluicing operations, but complaints are made by the miners that the ground is gradually getting poorer; and, indeed, the persons who have hitherto earned their livelihood by having tables in the bed of the river for collecting the gold coming down in the muddy water state that very little is got from this method now, showing that either the actual miners are taking greater care to save the gold, or else it is not in the ground. There is, however, a large deposit of auriferous cemented sand, both on the Charleston Flat and on Brown's Terrace, which is likely to pay small wages for a long time to come by employing suitable crushing machinery to work it. It will be seen from the returns of the Venture Company at Addison's Flat, which is said to be paying very well, that the yield of gold is only 1dwt. 14gr. to the ton, while William Fox crushed 2,800 tons for 52oz. gold. This is equal to an average of 8·9gr. to the ton; but even with this small average cement can be made to pay small wages for working.

Grey Valley.

There is still a large number of miners in the Grey Valley on the different diggings, and a great many more would be employed were a good supply of water obtainable. In the early days a great deal of the ground paid for paddocking and driving out, but there is now very little ground left that will pay for working by this method. At Granville, the Duffers' Creek Company are working ground that was partially driven out in the early days, and now they are sluicing it by having a drainage tail-race with a well. The ground is sluiced down into this well by having the sluice-boxes in the bottom of the paddock for saving the gold, and allowing the tailings to go into a well. These

are then lifted to a height of 70ft. by bucket-elevators, run away in a flume, and stacked in the creek-bed.

The elevators are worked by a Pelton water-wheel, which is erected on the surface of the ground. The water, after passing through the Pelton, is used for sluicing into the paddock. The value of the gold obtained by this company in six months prior to my visit in May last was about £900, and the expenditure for the same period was £530, thus leaving a net profit on the workings of about £370. This method of working is not equal to hydraulic elevating, but there is no available water-supply that could be got to work the ground on this principle.

At Orwell Creek a new discovery has been made in a large terrace at the head of Carriboo Creek. One tunnel has been put in, and the ground is said to pay about 10s. a day per man for working it. Other tunnels are being constructed, and it is probable a good lead of gold-bearing wash-drift may be discovered. In years gone by, rich auriferous gravel was found to go down the flat from Orwell Creek Township, and many miners are of opinion that a good lead of gold-bearing wash-drift will yet be found crossing the head of the Ahaura Plains at the lower end of Orwell Creek. This view is favoured, inasmuch that it is on the line of the ancient river-bed that has passed through Granville, River View, Callaghan's, Nelson Creek, Red Jack's, No Town, and Maori Gully. A large special claim of 200 acres in extent is held at the head of the Ahaura Plains, and it was mooted, during my last visit to the district, that steps are being taken to construct a tail-race through this flat, which will not only be a drainage-race, but at the same time prospect the ground.

At Moonlight and Blackball there are a considerable number of miners at work, and from what could be ascertained the most of them are making fair wages. During the last year there has been some new ground opened at Garden Gully, Moonlight, giving payable returns for working. It is thought to be the continuation of the same character of ground as that found at Steward's Hill, where a rush took place some time ago, but, unfortunately, the tunnel driven into the hill was not sufficiently low enough to bottom the ground. Recently, a party of miners went into one of these old tunnels and sank a shaft, and obtained about 9dwt. of gold off the bottom.

There are also some very fair claims at Callaghan's and Nelson Creek; at the latter place Larkins and party, Law and party, and Donnellan and party are said to be doing very well. The collapse of the flumes on the Government race has been a great blow to the district, as that was the only water of any consequence that commands the ground on the east side of Nelson Creek, and it was on this side where the principal mining operations were carried on. A company has taken up a tail-race from below Pott's Hotel to the ground underneath the valley of Nelson Creek, opposite Hatter Terrace Township, but up to the time of my visit to the place nothing payable had been struck in this direction. There is, however, some good ground near Pott's Hotel which the company intend to work.

At Bell Hill a company, formed principally of Christchurch gentlemen, have taken up a special claim of 50 acres at a place known as the Devil's Hole, and are constructing a water-race to get water to work it by hydraulic sluicing. The capital of the company is £3,000, which is considered sufficient to put the claim in working order. This ground has been a favourite spot for miners for a number of years, who worked the ground by means of tunnelling. There is little doubt when once the water is in, that this will prove a payable venture. The water-race is said to be very short and cheaply constructed, and will have a good supply for the most of the year.

There is an auriferous belt of country between Nelson Creek and Maori Gully which includes Red Jacks and No Town Diggings, but, except it is near one of these places, there has scarcely any prospecting been done. Gold was found in the same belt in some of the cuttings of the Midland Railway going up the west side of the Arnold River, and this same run of ground passed on to Dunganville. There is a good field for prospecting in the belt, and there is no reason why as rich patches should not be got as have already been worked at the old diggings. The most of the gullies and creeks which flow into the Grey River on the south side derived the gold found in their beds by cutting through this auriferous belt and concentrating the material, allowing the light particles to be carried on by the stream into the Grey River, while heavier gravels and gold were left in the beds of these streams.

Kumara.

Mining on this field has during the past year given results not greatly different to the yield of the previous year. One or two claims have been worked out, but the same parties or others have taken up an equal area of ground on other parts of the field.

During the latter part of the season a number of claims have been pegged out on a line nearly parallel with the south-west edge of the Larrikin's and Kumara Flat, and at a distance of from 20 to 30 chains from the rising ground bounding the Flat. The depth of sinking on the new ground in some cases is as much as 30ft. to reach the false bottom on which the more superficial gold-bearing deposit rests. The nature of the material is similar in character, if not so coarse, as the wash immediately west of the morainic hills of Dillmanstown, and is therefore due to the same causes—namely, the action of a considerable river prior to and during the advance of the Teremakau and Arahura Glaciers to the neighbourhood of Kumara, and, on the disappearance of the ice, to the sluicing and assorting action of a large volume of water which made its way over or between different parts of the morainic hills.

It has already been shown* that a large stream, the Teremakau, undoubtedly, crossed the morainic hills at the head of Larrikin's Flat, and found its way to the sea along the south-west side of the Flat. At that time the present channel of the Teremakau had not been formed, and the Greenstone must have had its course across the Flat formed by the pre-glacier rivers, and by the Teremakau when occupying a yet older channel than the first of those across the morainic hills of Dillmanstown. Gradually, or by successive stages, the river worked its way to the northward, forming and abandoning a series of channels through the morainic hills, till finally it settled into

* Goldfields Reports, 1893, p. 162.

that which it occupies at the present time. There would thus be formed a series of runs of gold, getting poorer, or, if not, wider apart from each other towards the north-west. The elder of these would be that most to the south-west; the youngest, the present channel of the Teremakau. By the shifting of the river-channel from point to point, where it made passage through the morainic hills, the different old river-channels appear to converge on a point higher up the valley than the site of Dillmanstown. This radial character of the different runs of gold has already been established by observation.

Mr. Gow, when in charge of the waterworks, paid a good deal of attention to this matter, and had exceptional opportunities for making observations and the collection of data bearing upon the subject. He described the different runs of gold crossing Larrikin's and the upper end of Kumara Flat as having the radial character alluded to, pointing out that different runs did not unite or focus at a point on the western side of the morainic hills. It is unlikely that the Greenstone ever had an independent course to the sea. Its first course would be the old channel of the Teremakau, which, by the general direction of the valley, would tend to a south-west course in the direction of Akers Creek and the lower Kapitea. The stream would thus join the Teremakau on the south-west side of the Flat, nearly in the direct line of the Greenstone Valley. The false bottom of Larrikin's and Kumara Flat is deeper in the middle and western sides than towards the north-east, in driving from the Teremakau, there being a ridge of "blue bottom" to be got through in order to reach the lowest gravels under the false bottom. The Teremakau in its present channel is thus, probably, below the general level of the blue reef over the flat lands on its southern bank. If there be sufficient inducement the ground can, therefore, at most places, be drained, by tunnelling from the river-bank opposite. The prospecting-shaft put down by the Kumara Prospecting Association showed that the false bottom under the upper wash is not so thick as has been supposed, bottom having been reached at from 95ft. to 100ft. from the surface. At most places a shaft 130ft. to 150ft. deep should reach the bottom. Thus, but for the great abundance of water in the lower strata, any part of Kumara Flat could be easily prospected to the blue reef, but, as matters stand, where adits cannot be driven to drain the water from the working-levels great difficulties must attend the working of the deeper ground.

At the present time the tendency seems to be to follow the shallower auriferous deposits along one of the old runs that are parallel to and at some little distance from the Kapitea Hill and the terrace bank, thence to the north-western end of Sandy's Hill. There is thus the possibility of a considerable area of new ground being opened up, which may pay well for hydraulic sluicing.

Gold was found in the deep shaft which was sunk through the false bottom, but the place where it was sunk seemed to be too near the Kapitea Hill for the deep ground, although the blue reef was dipping in towards the hill. Taking the level of the bottom of the shaft and the level of the drainage-tunnel, where the old river-gravels have recently been struck, it would appear that there is yet deep ground between the river and this shaft. Indeed, it may be found that there had been at one time two river-channels in this Flat, one alongside the foot of Kapitea Hill, and another through the centre of the flat. The drainage-tunnel had been constructed through the blue reef for a distance of nearly 700ft. when a heavy blue boulder wash-drift was met with; as soon as this was struck, a very large quantity of water was found. At the time of my visit to this field, in the end of May last, about two sluice-heads of water was coming out of the boulder-wash, which was overhead in the drive, and although it had been flowing at this rate for nearly a fortnight prior to my visit there seemed to be no diminution in the quantity of water.

The tunnel is only a short distance above the No. 3 channel, and there is always a large stream of water alongside this channel as leakage, and it is probable that this water is finding its way towards the present drainage-tunnel in the lower wash-drift; and, if so, there is very little likelihood of any diminution of the flow taking place. On the other hand, if the water was coming from the river-basin itself, it will soon become less, by being gradually drained off. The blue reef, through which the tunnel is constructed, will not stand for a great length of time without timber, it is now beginning to show signs of caving on the sides.

As year by year passes by, there does not appear to be much difference in the quantity of ground washed away. The most noticeable feature is, that the most of the claims working are getting up to the Larrikin's Road, which is completely washed away in one place. The workings, as they get nearer the Kapitea Hill, are getting more difficult, on account of the small fall that the miners can get for their tail-races. Still, some of the ground yet pays fairly well for working.

A considerable area of new ground has been taken up between the Long Tunnel Company's ground and the Hokitika–Greenstone Road, and very fair prospects have been obtained. At this place, 13 claims have been taken up, and 29 shafts sunk; and, taking the average prospects obtained, it shows that the ground will pay for hydraulic sluicing; but before any sluicing can be done here a tail-race will have to be constructed for about 70 chains, which is estimated by the miners to cost £4,500, and the head-race will have to be extended along the side of the Kapitea Hill for about 40 chains. There is a new tail-race in course of construction higher up the flat than where this ground is situate, which is being brought in to work another portion of the field.

Callaghan's.

There has been very fair gold got in Callaghan's Flat in Hyndman and party's claim. It is three years ago since this party sunk their shaft, but the water proved too heavy to be able to cope with by means of a horse-whins. Since then this party has constructed a drainage-tunnel for a distance of nearly 3,000ft., and succeeded in opening out the ground, which is said to contain about 4dwt. gold to the load of wash-drift. Another party has taken up a claim alongside them, and are making arrangements to get drainage into Hyndman and party's tunnel. Some of the ground nearer the terrace was driven out from shafts in the early days, and gave fair returns for working. There is a large extent of this Flat, and probably several leads of gold-bearing wash-drift will now be discovered.

There are several sluicing-claims on this Flat, on the edge of the terrace facing the Little Kapitea Creek; but these are working on a false bottom. The ground is too deep to allow them to be worked to the main bottom by sluicing, and there is no possibility of getting sufficient fall to admit of this being done. Several of the miners are waiting anxiously for the Callaghan's branch of the Waimea Water-race to be completed, in order that they can take up ground in this locality. On the top of the range, at the head of Italian's Gully, there has been some very rich ground, but the scarcity of water here makes the working of the ground a very slow process. Some of the claims have been worked here for the last twenty years, and still give payable returns.

Waimea and Stafford.

A good number of miners are still employed in this locality, but the ground is getting back so far into the terrace that the fall for the tail-races is so little that the same quantity of material cannot be shifted as was done in former years, hence the returns from the claim are gradually getting less. The ground is also getting deeper, and the same area of bottom cannot now be got over as was done in the shallower ground. The water-race is at a sufficiently high level to admit of the water being taken directly from it in pipes, but no one cares to go to the expense now to do this, as the fall for tailings is so little. The bed of the Waimea Creek is so filled up that any one who had been working there in the early days would not distinguish the place where they had been at work.

There is still a considerable area of ground higher up the valley, but very little prospecting has been done in this direction, as there is no water to be got to carry on sluicing operations, even had payable ground been found. There is also a large flat in the middle branch of the Waimea Creek, in which gold is known to exist, and some parties have been working it from shafts, but the ground has to be tolerably good to pay for working it by this method. However, as soon as the branch of the Waimea Race is constructed so as to command this ground, it will give facilities for its being taken up and worked, and no doubt many of the miners who are now working ground lower down the valley will turn their attention to this ground as soon as the water is in. There is very little ground in this locality that is not auriferous, but it requires plenty of water, with a good head to wash it away in a wholesale manner, to give wages for working it.

On Kelly Terrace Mr. Batchelor has gone to considerable expense in opening out his claim, and he is now in a fair way of working. He sluices the material into a paddock, in which there is a large well, where the water passes down through a tunnel tail-race, and the tailings are lifted by bucket-elevators. These elevators are worked by an over-shot water-wheel, and the same water which is used on the wheel flows into sluice-boxes at the head of the elevators and carries the tailings away. He purchased this claim from the Wheel of Fortune Company some years ago, and informed me that it has cost him, up to the date of my visit, about £4,000, including the plant he has erected. The water-wheel that he uses gives, however, too little power to work his elevators, but if he were to get a Pelton wheel he could easily get sufficient power to do all that is required. The ground that he is working is highly-cemented gravel, and the head of water on the sluicing-nozzle is not sufficient to break it down and disintegrate it so as to let the particles of gold free. He, however, contemplates making further improvements, to get a larger quantity of material put through.

Gillam Gully.

On the northern side of the Arahura Valley, near its mouth, the southern slopes of the hills lying between there and the Waimea Valley, at Stafford Town, are first river-terraces resting towards the east on Miocene sand, or on the overlying gravel formation known as "old-man bottom." More to the north-west the same beds necessarily overlie the northern continuation of the marine terraces, of which the Hau-Hau Terrace is the most important development in this part of the Westland District.

The marine auriferous beds show in Ballarat Terrace, and thence strike across the valley at the lower end of Stafford Town, north of which they are gradually restricted in the breadth of their exposure.

In Gillam Gully the Stafford Prospecting Association have been carrying on prospecting operations for some time past, and recently they have been successful in obtaining gold of a very coarse character. Skipper and party, who were employed in sinking a shaft and driving, showed me a sample of the gold they obtained, and from its character there is little doubt but that they are not far from a rich auriferous deposit. The Association have taken up a claim of 6 acres, and have agreed with Skipper and party to give them 1½ acres of the ground and to carry on further prospecting in this locality.

Humphries Gully.

The beds forming the Humphries Gully deposit have been frequently described. They consist of coarse gravels and beds of finer grit and sand resting on a grey or blue laminated sediment, a silt on plastic clay. In this underlying clay there are subordinate bands of fine or coarse brecciated material, chiefly granite, but which differs from the gravel beds of the higher part of the Kanieri series in this respect—namely, that the latter, though chiefly of granite material, show always well-rounded gravels. The great thickness and weight of the gravels near the open face of Humphries Gully Claim presses on the plastic clay underlying, so that it tends to escape from underneath the gravels, and near the working-face rises into mounds and hillocks, illustrating many curious problems in stratigraphical geology; but, at the same time, doing no little damage to the pipe-lines conveying water to the nozzles at the working-face.

Scattered over the higher slopes of the range east and south of Humphries Gully there are morainic deposits that have been greatly denuded, but of which there yet remain many large blocks of schist and other rocks, which, with finer material of the same description, may be a source of gold to Humphries Gully, but which need not be considered in making an estimate of the future productiveness of the Humphries Gully Company's claim.

The gravels worked are referred to by Mr. McKay as the youngest of the series of littoral or fluviatile gravels that accumulated in the great valley depression of the West Coast subsequent to the deposition of the highest beds of the marine Miocene series, or Kanieri beds, so widely developed over the low grounds between Ross and the upper part of the Grey Valley.

They have a very extensive development in the range of hills lying between the Arahura and Kanieri Rivers, and they should be auriferous at other places besides Humphries Gully, so that here there is a large field over which hydraulic-sluicing operations can be carried on. The chief difficulty in connection with the development of this field is the great cost of water-supply sufficient to conduct operations on a large scale.

The Humphries Gully Company having let the claim to tributers, these during the past year have been very successful in their operations. Gold to the value of £4,005 4s. 10d. was obtained, of which one-third went to the tributers and two-thirds to the company. For this tribute paid, the company has spent—£350 4s. 10d. on plant extension; main-race maintenance, £372 18s. 6d.; rent and fees, £132 12s. 7d.; and about £323 16s. 3d. to the tributers for other work other than the tribute they were entitled to receive. Taking the total amount paid to the tributers for working the claim, including payment for necessary repairs outside their agreement—namely, £1,658 17s. 10d. —the whole expenses, exclusive of management, directors' fees, and travelling-expenses, and agencies in London and Auckland, which amounts to £327 18s. 6d.—there was a net profit last year, after the payment of working-expenses in connection with the claim, of £1,002 11s. 1d. This shows that, with an abundant supply of water, this would be a valuable property. The directors' estimate that there was still about £750 worth of gold left in the boxes, which was not washed up. It is really a pity that some effort is not made to get the necessary capital to extend the head-race to the Arahura River, where a never-failing supply of water could be obtained.

The capital of the company, which now stands at £139,984 after deducting the reserved and forfeited shares, is far too large to pay interest on. The present shareholders will have to be content with less interest in the concern if they wish others to join them in the enterprise and find the necessary money to extend the head-race so as to make it a payable venture. A proposal is now made to re-form the company, with a capital of £60,000, consisting of 60,000 shares of £1 each; of these, 30,000 shares are to be given to the existing shareholders fully paid-up. The remaining 30,000 shares is proposed to be issued as preference shares, carrying a preference dividend of 10 per cent., and also a preference in capital. Of these preference shares, 5,000 are to be deemed fully paid-up and allotted as bonus shares to the subscribers of the new capital. After each of the two classes of shareholders have received a dividend of 10 per cent., the surplus profits are proposed to be equally divided among all the shareholders. The proposal seems a fair one for the new shareholders, as they have to receive a dividend of 10 per cent. before the present shareholders get a penny, and £3,000 is not a large profit on a venture of this description.

Blue Spur.

During the past year there has been a discovery in this neighbourhood. The Hau-Hau lead, running along the eastern margin of the Hau-Hau Terrace, was in the early days of the West Coast traced from opposite the Township of Kanieri to the southern bank of the Hau-Hau Creek, opposite the Blue Spur, but not across the low grounds of the valley to the terrace spur separating this from the Lower Arahura. Rich gold-bearing deposits were, however, worked in Scottie's Terrace and on the opposite or northern side on the fall towards the Arahura, and on this side was traced across the road till lost in the deep ground of Dyer's Flat. The gold could not be traced further to the south-west, and within the limits traced the ground was too wet to follow it to a greater depth than 30ft.

For several years Mr. Boys, of Blue Spur, was engaged in bringing up a low-level tunnel with the object of draining this deep ground, and to do so has driven a tunnel nearly a mile in length, starting from the southern bank of the Arahura. This gigantic work taxed the energies and the means of the plucky prospector; but a judicious aid from the department enabled him to complete the work, with the result that gold was struck a little earlier than was expected. This led to several claims being pegged off to the east and north-east of Boys' claim, and at least one shaft (Harcourt's) has been bottomed on gold. The ground, however, is wet, and till connection with Boys' tunnel (10 chains distant) is made, work has been suspended in this claim. From the bottom of Boys' shaft 24dwt. of gold were said to be obtained, and 8dwt. from the bottom of the shaft on Harcourt's claim; and there is a probability that as the ground is worked to the south-east, or towards the line of the old lead, where this was worked to the water-line, the ground will be richer than where recently proved.

The sinking to reach the gold-bearing gravels resting on blue Miocene sandy clays of the Kanieri series was from 48ft. to 54ft. The upper part was through river gravels, and there are no traces of glacier deposits on the ground. Shortly before reaching the washdirt the river gravels give place to marine beach-shingle, having a considerable percentage of black sand, which oxidized forms a hard band impervious to water. Below this the wash, 4ft. to 5ft. thick, is loose and easily driven on, the cement stratum above forming an excellent roof.

There can be no doubt that this is the continuation north of the Hau-Hau lead, the auriferous wash being the same in character, and at about the same level. On the lower slopes, towards the Arahura River, the lead has been broken up, and its gold carried away, probably enhancing the richness of leads at lower levels and the black-sand beaches near the mouth of the river. Heavy river gravels have taken the place of the marine gravels, and those driven in by Mr. Boys for some 4,000ft. yielded scarcely a trace of gold.

Since this discovery was made several other shafts have been bottomed, but no payable washdrift was obtained. This, however, is no criterion but what a lead of gold may be found traversing the flat for a considerable distance. There is a large area of unworked ground in this locality, but until such time as a connection is made with Mr. Boys' drainage tunnel, to allow the ground to be opened out, very little can be said respecting it.

Kanieri.

At Kanieri there is a line of morainic hills similar to those worked for gold at Kumara. The down-valley slopes of these and the succeeding flat are covered with well-washed river or beach gravels, that have been to a large extent worked for gold.

The line of morainic hills, extending east along the foot of the range towards the Kanieri Forks, is gold-bearing; the lower gravels passing under the more angular detritus have been the principal gold-bearing bands; claim-working having been pushed forward on the south-east faces of these hills till the less auriferous overlying angular material formed too deep a face for profitable working with the power and appliances at hand.

Commissioner's Flat, lying on this side of the line of morainic hills, formerly yielded a large amount of gold, and is still considered to be very rich in the deeper parts.

The development of mining in this part of the district has been retarded by the lack of a sufficient water-supply, and the low level at which the richer deposits of gold are found on this side of the Hokitika River.

A band of solidly compacted wash crosses the Hokitika a little below the Kanieri Bridge. This contains boulders of considerable size, and these proved an obstacle to the dredging of this deposit in the bed of the river, which was attempted during the past three years, with, however, not very satisfactory results.

Dredging at the Kanieri was originally started in the channel of the river, with the view of reaching tailings thought to contain gold, and to dredge a line of wash-drift which had been worked to the bank of the river at the place where dredging was commenced. Whether the last of these was the material last operated upon it might be difficult to determine, but, in any case, different means had to be resorted to break or blow up the bottom before the dredge could operate upon it.

It would appear that this band of auriferous wash, crossing the river at and a little below the bridge, underlies at least the higher part of the morainic hills at back of the township. Immediately on reaching the southern bank of the river the direction of this deposit changes to the south-east, and follows the foot of the high terrace to and beyond the road leading up the terrace-face to Rimu. Woodstock diggings are therefore on this part of the line.

There are very few miners now working at Kaneri; it almost has the appearance of a deserted diggings, were it not for the number of houses in the township. The miners are scattered about the place in different gullies and flats. Still there appears to be some of the ground at the back of the township that has never been properly worked; also on the lower end of Commissioner's Flat there is still a good area of solid ground. Kane and party have sunk a shaft directly at the back of the township, near the foot of the terrace, where they were pumping the water with a jet-pump to a depth of 6ft. 6in. They have about 200ft. of 7in. wrought-iron pipes, with a hydrulic head of 54ft.; but the quantity of water there is to lift is too much for the size of the pipes that are used, there being too much of the hydraulic head absorbed in friction.

Marks and party have a claim on the lower end of Commissioner's Flat, which they drain with a jet-pump; but they have a hydraulic head of 80ft., and use 1,400ft. of 9in. pipes. This lifts the water 13ft. and works extremely well. There is a considerable area of solid ground where this party is working, and the claim is paying them very well. A little above where they are working very good gold was got in the early days; but as it came down the flat the water became too heavy to contend with. This party has, however, overcome this difficulty, and likely to get well paid for their labour.

Cadman's Terrace.

A new discovery has recently been made about nine miles up the river from Kanieri, at a place where prospecting operations were carried on for a considerable time by Antonio Zala on behalf of some Hokitika gentlemen for coal at the back of the Gentle Annie Range, facing the Valley of the Kokatahi. The Rimu Miners' Association, who have been doing really good work, sent some men to prospect in this direction. The prospectors' claim is known as Retheivitch or Bancke and party, who have got payable gold. The following are the claims taken up at the time of my visit on the 30th of May last:—

Name of Party.	Number of Men in Claim.	Depth of Shaft sunk.	Remarks.
		Ft.	
Banks and party...	4	62	Getting gold.
Mahary and party	6	65	" " "
Joyce and party	5	...	Not bottomed.
McGovan and party	6	40	Beat out with water.
Jones and party	5	10	Sinking.
White and party	4	...	Not commenced to sink.
Singer and party	5	34	Shaft in tunnel and getting gold.
Cuming and party	6	45	
Zala and party	6	30	
Sullivan and party	6	...	Just started to work.
McQuillan an party	5	54	
Milligan and party	5	...	Just started to work.
Kane and party	5	...	" "
Irvim and party...	6	...	" "
Total number of men ...	74		

Some of the shafts are very dry, but in other places sinking is abandoned owing to the large influx of water. The miners were proposing to construct a drainage tail-race, which they state will be about 500ft. in length. The quantity of gold that is being got is not great, and the scarcity of streams in the locality prohibits them sluicing the wash-drift, the whole of it being cradled, which is a slow process; and the average yield of gold, so far as the claims are bottomed, is about 2½dwt. to the load. There is a considerable extent of ground on this terrace south of the prospectors, but until the drainage tail-race be brought up many of the shafts will not be bottomed, so that very little is known regarding this find at present.

Rimu and Back Creek.

The depression between the edge of the high terrace overlooking the lower part of the Hokitika Valley and the morainic hills to the south-west is clearly an old channel of the Hokitika River. The upper part, known as Back Creek, is deeper and not so wide as the part below the main road through Rimu Township. Whether the whole volume of the Hokitika passed along the Back Creek may be doubted, yet may easily have been the case. At Rimu, however, either the river after a time abandoned the upper part, and with its whole volume entered the old channel close to where the road from Kanieri passes over the terrace, or the branch along Back Creek was augmented by a further large volume of water gaining access at this place.

The gold-workings on Rimu Flat, below the road, appear to be entirely through river shingle to the bottom on which the gold is found. Thus, it may be that the glacier detritus and the underlying river gravels of older date have been swept away, and in the channel thus formed the newer gravels formed by the Hokitika were deposited. It is, however, different along that part of the old channel south-east of the main road. The morainic deposit has not been cut through, and the slopes forming the banks of the old channel of the Hokitika show clearly that they are formed of very coarse angular glacier detritus. In the gully of Back Creek, it therefore follows that river shingle is first met with, and then, beneath that, angular, or more or less rounded, material of glacier origin. But below the glacier accumulations, there lies another series of river-gravels that were deposited prior to the advance of the glaciers to this point. These lower gravels rest on brown sands belonging to the Kanieri series. They show, and are worked as open sluicing-claims, in the face of the terrace overlooking the low grounds of the Hokitika Valley. They have been followed under the morainic deposits to and beyond the line of Back Creek, and prospecting in these beds under the morainic hills is being pushed to the westward, beyond the valley of Back Creek, in the direction of the road to Ross.

These lowest and older river-gravels, as they must at many places have a great thickness of moraine above them, cannot thus be operated on as open sluicing-ground, and have, therefore, to be rich enough to pay for driving out before they can be worked. At other places they may be nearer the surface, and in such cases they could be worked as open sluicing-claims.

The Miners' Association at this place has been carrying on a good deal of prospecting operations in the district during the last year. According to the statement presented by the Committee of the Association, the work done for nine months ending the 6th April last was as follows:—

Name of Party.	No. of Men.	Date of Application.	Date when last Measured up.	Distance Driven.	Distance Sunk.	Amount of Payments.	Locality.	Wages earned per Week per Man.
				Ft.	Ft.	£ s. d.		£ s. d.
Milner and party ..	5	4th July, 1893	1st Aug., 1894	144	..	14 8 0	Constitution Flat, Kanieri	0 12 4½
Rankin and party ..	4	4th July „	6th March „	752	..	59 0 0	Stoney Creek, Kanieri Forks	0 9 1
Quin and party ..	3	1st Aug. „	4th Sept., 1893	..	81	15 1 0	H.H. Track	0 12 7
Davis and party ..	3	7th Aug. „	12th Oct., 1893	..	106½	22 19 0	Welshman's Terrace, Ross Rd.	0 17 0
Hamilton and party	3	8th Aug. „	9th Feb., 1894	74	176	61 0 8	Head Frosty Creek	0 15 7½
Spence Bros. ..	4	8th Aug. „	25th Sept., 1893	..	82½	16 10 0	Eel Creek	0 11 9½
Barnett and party ..	2	20th June „	8th Aug. „	22	..	1 2 0	Brennan's Creek, Hauhau	1 2 0
Dobson and party ..	3	16th Oct. „	31st Oct. „	..	25½	1 5 11	Welshman's Terrace	1 5 11½
Harris..	1	3rd Oct. „	23rd Dec. „	101	..	5 1 0	Aylmer Lead	0 9 0
Hill and party ..	3	9th Jan., 1894	6th March, 1894	63	31	16 8 0	Rocky Creek, Ross Road	0 13 8
Fluety and party ..	3	9th Jan. „	6th March „	29	75	21 11 0	Deep Creek, Seddon's Terrace	0 18 0
Ritheivitch and party	3	9th Jan. „	6th March „	..	36	8 2 0	Coal Creek, Rimu	0 6 9
Spencer and party ..	3	13th Feb. „	6th March „	..	18	3 12 0	Constitution Hill	0 8 0
Buchanan and party	3	20th Feb. „	6th March „	50	..	5 0 0	Welshman's Terrace	0 16 8
Total ..	..	..	..	1,235	631½	240 12 7	..	..

It will be seen from the foregoing statement that 1,235ft. of driving and 631ft. 6in. of sinking has been done, at a cost of £240 12s. 7d., which is an average rate of about 2s. 6¾d. per foot. So far, the result of the operations have not been attended with success; but the whole of the work has been done in a part of the country where leads of gold-bearing drift ought to be found. The whole of the country in this locality is covered with a great depth of glacial deposit, which makes prospect-

ing an expensive undertaking. The work done by the Association shows that no money is wasted, and that they get a large amount of work done for very little. It will be seen that the highest wages earned only amounted to £1 5s. 11½d. a man per week, while the lowest was only 6s. 9d. No one would work for this, were it not that there is always a chance in prospecting of striking payable gold which would repay them for their labour.

As far as the top drifts are concerned, there is very little chance in striking anything rich between Back Creek aud the Ross Road until the formation under the glacial deposit is reached. Any gold got through the glacial drift will be in layers, where a stream of water has been flowing in a channel which would wash away the lighter sands from the drift, and leave any gold and denser portions behind; in fact, the gold got at Seddon's Terrace is from a concentration of the glacial deposits effected by a stream of water. The older drifts are below this deposit; but it is a question whether these have not been carried away, and probably nothing now remains but the "Brighton bottom," which is older than the miocene gravels about Ross. There is a place near Ogilvie's Hotel on the Ross Road, at a creek which discharges into the Mahinapua Lake, where the Hokitika River had at one time flowed, and cut through the glacial deposit, and even now, in very high floods, it comes over the saddle into this creek. Some gold should be found amongst the boulders in the bed of this creek, as the work of concentration has been carried on here by the waters of the Hokitika. It is probable that the water cut through the drift to a considerable depth, and that afterwards the sides of the channel fell in, and blocked it up, turning the waters of the Hokitika River down its old course. If such be the case, the bed where the thickest concentrated layer of material will be found will be below the bed of the present creek; but, be this as it may, the present creek-bed to the east of the road should contain a little gold amongst the boulders.

The gold found further to the seaward on the Aylmer lead has been deposited there by the action of the sea, and came from a different direction and from different material to that of the glacial deposits. This lead was lost coming towards the southern end of Lake Mahinapua, and it becomes a question if it has not been cut off by the glacial material on the south and west sides of the lake, or it might be found underlying it. The same lead is found again further to the northward, and passes through Mr Craig's freehold on the southern side of the Hokitika River. There is little doubt but that the lead will yet be traced from Craig's freehold in a southerly direction.

There is still a limited number of men working at Rimu and Back Creek, but the ground in this locality is far from being rich. With the exception of those who have a fair supply of water to carry on regular hydraulicing operations, only small wages are made by working the ground from shafts and adits. It has been a question with the miners in this district as to the feasibility of bringing in a large water-supply at such an elevation as would work the ground on Seddon's Terrace by hydraulic sluicing, but the expense of such a water-supply would not be recouped, owing to the small number of men that would get profitable employment even were the water on the ground. If the cost of opening up the ground and the construction of sluices and tail-races be added to the cost of a head-race, to carry, say, 60 sluice-heads of water, it would require a net profit on the working each year of at least £3,600 to pay 3 per cent. on the outlay, without anything towards a sinking fund to recoup the cost of construction.

Ross.

There are a few miners at work in different places along the gullies and creeks in the neighbourhood; but on Ross Flat, where the principal mining operations were carried on in years gone by, there are only a few parties working on the upper levels, who are paying a small tribute to the Ross United Company. The principal operations on the flat are carried on by this company, in what is known as the Elevator Claim. This claim has been continuously worked by tributers, who pay the company 35 per cent. of the gross yield of gold. During the past year there were two shifts of men employed, who operated on 68,730 cubic yards of material, which yielded 715oz. 7dwt. 8gr. gold, representing a value of £2,789 19s. 6d. Of this amount £1,613 10s. went to the tributers, and £976 9s. 6d. was paid the company. This shows the yield of gold to be equal to about 4·96gr. gold to the cubic yard.

This company have another claim at Donoghue's, which is worked by elevators—that is, the material is sluiced into a well and the tailings are lifted with bucket-elevators to the surface, whilst the water is carried off by an underground tail-race to near the ocean beach. The total yield of gold last year from this claim was 347oz. 18dwt. 12gr., representing a value of £1,356 17s. Of this amount, £298 16s. was paid to the company, and £1,058 1s. was retained by the tributers, which is equal to about 22 per cent. of the gross yield of gold that the company receives in tribute. Taking the balance-sheet of the company for the year ending the 26th January last, it shows as follows:—

Receipts.	£	s.	d.	*Expenditure.*	£	s.	d.
To percentage of gold from tributers ..	1,342	7	0	By working expenses incurred by the company, including mine-manager's salary	952	18	8
Sales of water	102	0	0				
Sale of mining material	12	13	0				
Interest and discount	26	1	0	Management, directors' travelling expenses, stationery, law costs, &c.	413	4	7
					1,366	3	8
				Profit of	116	17	9
	£1,483	1	0		£1,483	1	0

This shows that, although the profits are small, it leaves a balance of £116 17s. 9d. of profit on the year's transactions, which is a very small amount on a capital of £150,000, less forfeited shares, £529 12s., leaving the capital of the company at £149,470 8s. The operations of the company for many years past show that, by the present mode of working, there is no hope of the shareholders getting any or very little of their capital returned, and that, unless operations are carried on in the deep workings, there is no prospect of recovering any money from the venture. It will require a

considerable capital to open out the deep ground, much heavier pumping-machinery will be required and a cheap method of carrying on operations will have to be adopted, to make the ground remunerative for working. It is not possible with a small expenditure to bring in a large stream of water as a motive-power, but probably, if a survey were made, it would be found that with a comparatively small expenditure, sufficient power to work dynamos could be got from the Mikonui River, and thence convey the electricity to work the pumps at the place where the operations are carried on. Even this would cost a good many thousand pounds; and, if ever the deep workings are again opened out, provision will have to be made to take out the whole of the water standing in the old workings, so that the whole of the flat can be systematically worked. The difficulty the present company is labouring under is, their capital is all gone; and no one will invest their money in such a venture unless the interest of the present shareholders be reduced to a nominal sum, so as to induce others to join with them in bringing the venture to a successful issue. There no doubt is a considerable quantity of gold in the deep ground in this flat, but the question at issue is—can it be obtained at a cost to repay the capital required to open up the ground, with fair interest. Taking the returns in the past, and from what is known about the ground, it would not be likely to pay back a capital of £150,000 with interest.

Mont d'Or Company.—This has been a dividend-paying company for many years. It is held by only a few people, and it will take a life-time to work out the present holding. All the available water-rights in the neighbourhood belong to the company, with the exception of those belonging to the Borough of Ross, who are the present holders of the Mikonui Water-race; but this race has to be constructed into the watershed of the Totara River before any water-supply can be obtained. The company hold all the water-rights in Donnelly's and Scandinavian Creeks, and are renting the constructed portion of the Mikonui Water-race to convey the water to the ground. During the year ended the 30th November last, gold was obtained to the amount of 1,623oz. 11dwt., representing a value of £6,382 15s. The expenditure on the claim was for wages, salaries, and other expenses, £3,884 14s. 6d.; on the water-races, £580 5s., making the total expenditure in connection with the working of the ground, £4,464 19s. 6d., thus leaving a balance of profit on the workings for the year of £1,917 15s. 6d. The paid-up capital of the company is £10,800, and the profit on the working last year is equal to nearly 18 per cent. on the money invested. This was not, however, all profit last year, as the company had to construct a deviation of the road from Ross to Donoghue's, in order to have more room for tailings; this deviation cost £990 5s., but even deducting this it leaves a good margin of profit.

Otago District.

Maraewhenua.

This field has extensive gold-deposits of moderate richness, but labours under the disadvantage of an insufficient water-supply. The gold is obtained from three distinct sources—viz., First, the base of the quartz-drifts at the bottom of the series of rocks of which the Oamaru building-stone is the highest member in the development of these rocks near Livingstone. Second, the upper beds of the quartz-grit and the first 2ft. of the overlying greensands, which have the peculiarity of being auriferous, while at the same time the greensands contain numerous fossils in the shape of sharks' teeth and shells of marine mollusca. A very considerable thickness of brown or grey sandy beds overlie these latter, separated into two divisions by a thick bed of volcanic rock, and, at some distance to the east the whole is overlain by what is known as the Maraewhenua limestone, as this is developed along the southern side of the Maraewhenua River. This succession of strata is illustrated by one of the sections accompanying Mr. McKay's report, and the section proves distinctly the age of auriferous deposits underlying the higher beds of the series. The third auriferous deposit consists of coarse river-gravels, brought down by the Maraewhenua at a time when its channel was at a level some 200ft. or 300ft. above what it is at present. These latter beds are chiefly developed on the north side of the Maraewhenua Valley. The gold-workings are partly in all three of these deposits, but chiefly at the present time in the upper part of the quartz-grit and the greensands, as already described, or, where the grit is of no great thickness, the whole is worked to the bed-rock. The coarse gravels of latter date are also being worked. The yield of gold is pretty uniform wherever the upper grits and greensands are worked, and in the greensand the gold is of an impalpably fine description. Samples of these greensands were lately forwarded to the Mines Department at Wellington for the purpose of ascertaining the true character of the gold found in the greensands. It appears that Mr. McKay was shown some gold taken from a claim on the north side of the Maraewhenua, which, though exceedingly fine in grain, as seen with a good lens showed as round plump gold, not flattened or abraded by the action of running water. This gold was for the most part derived from the greensands and upper beds of fine quartz-grit; and the question has since arisen whether, under any possible circumstances, such gold might have formed as a precipitate in sea-water. The greensand samples forwarded unfortunately did not contain gold, while the upper and finer-grained grits showed the presence of very fine but flakey gold, so that this question must for the present remain undecided. Though no gold was found in the samples of greensand sent, Mr. Gow, Inspector of Mines for the district, who procured the specimens, informs me that it is a well-known fact that very fine gold does occur in the greensands on both sides of the Maraewhenua Valley, but that the procuring of a sample of this separate and by itself is not an easy matter, as many dishfuls of stuff might be washed without seeing the colour.

On the north side of the river the auriferous ground extends to the Otekaike Valley, while to the south it reaches to the Kakanui Gorge. The constancy of the returns from this field should insure a certain amount of working being done on it for a long time to come.

The quartz-grits, &c., extend south across the Kakanui Gorge, through Balruddry and Kauroo Runs, and along the lower slopes of the Kakanui Mountains to the Otepopo River, beyond which the same beds can be traced to Trotter's Creek and the Horse Range.

The quantity of gold obtained from this field last year shows an increase over the previous one of 601oz., the yield last year being 2,397oz., representing a value of £9,849, as against 1,196oz., having a value of £7,358 for the year previous. The scarcity of water on this field limits the mining population. There is room here for a large number of miners if a plentiful supply of water could be obtained to command the field. This, however, is out of the question, unless at such a cost that the benefits derived would not compensate the large expenditure.

Lower Shag Valley.

There is a large development of breccia-conglomerate on both sides of the main road across the Horse Range. Similar beds form a considerable development in the north-eastern part of the downs flanking the south-west slopes of this part of the Horse Range. The beds are fairly well exposed in the road-cuttings, and are seen to consist of slaty breccia-beds, followed by beds of quartz-grit. At several places gold has been found in these beds, but till recently they have not been worked in the low ground in front of the range. Last year gold in paying quantity was found in a small gully running through part of Mr. MacGregor's farm. This gully, on being worked, paid well, and the gold was traced beyond MacGregor's land to the head of the gully springing from the adjoining ridge, formed of breccia-conglomerates and quartz-drift, on the higher parts of which gold can be washed from the soil at any point, but not as a paying prospect. The area of recent alluvial ground at this place is necessarily of small extent, and the paying parts of it are even now exhausted; but there is thus clearly indicated the auriferous character of the breccia-conglomerate and quartz-drifts, from which the gold obtained has been derived. These breccia-conglomerates, &c., extend parallel to the range, at the foot of which they lie, a distance of fully a mile, as beds clearly exposed at the surface; and they are of great interest, as forming on MacGregor's farm an illustration on a smaller scale of what took place at Gabriel's Gully and the Blue Spur. Whether the breccias or grits at this place will be worked for gold remains to be seen. Water cannot readily be brought on to the ground, and the disposal of tailings would also be a difficulty, which only the great riches of the deposit would warrant contending with.

Horse Range.

Gold has been worked intermittently during the past twenty years on the south-west side of the Horse Range, near where it is crossed by the road from Oamaru to Palmerston. Two gullies leading to the top of the range, near where the road crosses, yielded most of the gold found, and clearly indicated the breccia-conglomerates at the base of the coal-bearing series as the source of that gold. These gullies are now supposed to be completely worked out, and any further exploration for gold will have to be carried on in the adjoining breccias. These are well worth prospecting in positions where water could be had to work them; but this could only be on the north-east side of the range, where a small supply might be obtained from Trotter's Creek.

TUAPEKA DISTRICT.

Alluvial mining in this district is now chiefly confined to the working of the breccia-conglomerates of the Blue Spur, and the re-working of portions of Gabriel's Gully and Evans's Flat, dredging on the Waitahuna Flat, at Havelock, and the working of one claim in the breccia-conglomerate of Waitahuna Gully, where also a dredge is at work, and one or two parties re-working the margins of the gully or sluicing the loamy deposits of the hill-slopes on the north-west side of the gully.

Blue Spur.

Under the management of Mr. Jackson, the works of the Blue Spur Gold Mining Company are being conducted with energy and skill.

In the last year's report, an account and description of the Blue Spur deposit was given as an extract from a paper by Mr. T. A. Rickard, an American mining-engineer who recently visited New Zealand, and examined the deposits in question. More recently, during the early part of the present season, Mr. McKay, Geologist to this department, was instructed to make a general examination of the more ancient auriferous drifts of the goldfields of Otago; his report on which, now published, affords a great deal of valuable and additional information respecting the mode of occurrence of the deposits that were the subject of his examinations.

Mr. Rickards's description of the Blue Spur is cited as the best available, and as, in some particulars, affording information the facts of which are no longer open to investigation. Mr. McKay, however, adds important observations of his own, which were verified by myself as regards some particulars when the locality was last visited by me.

Mr. McKay shows that the Blue Spur deposit is in no sense a local deposit in a small lake depression, or mountain tarn, or expansion of an ancient river, supplied by berglets broken off the terminal face of a glacier, coming from no one knows where. The Tapanui Mountains have been indicated as the source of the jasperoid boulders that occur abundantly in the lower part of the Blue Spur deposit; but, it being noted that these are highly crystalline rocks, schistose in structure, and in many cases full of crystals of magnetite, it was concluded that the river supplying the deposit did not come from nor course past the Blue (Tapanui) Mountains, but came from a more auriferous district in the central region of Otago.

The indurated jasperoid shales or red-slate of the Maitai formation is a quite different rock; and in the Blue Spur the purple hæmatites are dissociated from the sandstone gravels forming the higher part of the deposit, in which they rightly should have been found, were their source the Tapanui Mountains.

Mr. McKay maintains that the Blue Spur deposit is part of a wide-spread formation represented in the Kaitangata Coalfield by the schistose slaty breccias that are there found in connection with and forming part of the coal-bearing series; that the same beds have a very large development in the south-eastern part of the Horse Range, where they form the basement beds of the Shag

Point Coalfield, and, as such, appear in Mount Vulcan, near the mouth of the Shag River. Here, also, the beds are gold-bearing, reference to which fact will be made in the proper place.

Between the Blue Spur and the old Woolshed diggings at Glenore, there are several small patches of these breccia-conglomerates, and these, nearly all of them, lie in the direct line between the two points mentioned. This has been thought to be the course of the old river or glacier which deposited the Blue Spur gravels; and there, also, Mr. McKay explains the matter otherwise. Mr. Rickard, indeed, noted that on the eastern side of the Blue Spur deposit the smooth wall of rock indicated a slide or fault; but did not note that the line of this, projected to the south-east, would roughly constitute the eastern boundary of like deposits at Weatherstones, Waitahuna, Manuka Hill, and Glenore. Along Waitahuna Gully the fault is as clearly traceable as at the Blue Spur, and at Glenore Railway-station it is inferred from the occurrence of the breccia-conglomerates in the bed of the stream, while the steep banks on the north-east side show the presence of schist. A fault bounding one side of the Blue Spur deposit is shown on a map by Mr. McKay, indicating the distribution of the great faults and earthquake rents of more modern times in both islands of New Zealand.*

The line of fault, as traced to the north-west, thrice intersected Lake Wakatipu, and reached the West Coast a little north of the entrance to Milford Sound. In the opposite direction it reached the sea-coast a little south of the mouth of the Taieri River. Its course, as now determined, is more north-west and south-east. Along the line, so far as traced, lie six small areas of breccia-conglomerate, practically the same in character at all the localities, and also occurring under a similarity of conditions—that is, they seem to rest in depressions of the surrounding rocks. This peculiarity has been explained in Mr. McKay's report, already referred to, in which the opinion is advanced that the Blue Spur deposit constitutes the earlier proceeds of the denudation of interior Otago, after the exposure of a considerable area of the schist rock; and that what now distinguishes these breccia-conglomerates from the younger and overlying quartz-drifts was due to their being deposited in the hollows of the old land surface, and thus escaped reduction to the condition of quartz-drift, which, on the submergence of the land, was the case when the deposit was of lesser thickness or more exposed to the action of the advancing tide, which submerged the greater portion of eastern Otago, and reached as far to the westward as the middle part of the Maniototo Plains.

Blue Spur Company.—The whole of this company's workings is now confined to the cement, and it is gratifying to find that this material is being made payable for working. There is no doubt this company is heavily handicapped in having given far more than its value for the ground to the different companies which originally held it. These companies, working it as long as they could make it pay wages, took out all the best of the ground and then sold it for a fabulous price in comparison to its actual value. However, although the ground proved that the gold-returns will not come up to the company's first anticipation, it may consider itself fortunate in that it is being made payable for working with small profits; and, were it not for the careful management and the ability of the gentleman in charge of the work, who closely watches all the operations, this company, like some more of the English companies who have mining properties in the colonies, would have been a failure. It is customary for companies who are formed in England to send out a manager to conduct the operations; they do not seem to have any confidence in colonial men being in charge of their properties. The real result of this is that men are sent out who have to learn a great deal in their profession before they can successfully conduct the operations of any company. The formation of each country differs greatly, and also the auriferous and argentiferous deposits occur in different forms even in the country itself. A man may be, for instance, a splendid manager for a quartz company at Coromandel in the North Island, but if he was sent down to Reefton in the Middle Island to take charge of a quartz-mine he would have a great deal to learn there before he could reasonably expect to conduct the undertaking successfully. In fact, the companies who employ managers not acquainted with the formation of the district where the operations are conducted, have not only to pay for a portion of their education, but also, in many instances, to pay heavily for the mistakes made in the carrying-on of useless works. We have equally as able and trustworthy men in the colony to manage mining properties as there are in other countries, and these are certainly better qualified to conduct the operations of a mining company in this colony than those coming from other parts of the world. This is clearly demonstrated in the case of the Blue Spur Consolidated Company.

Taking the operations for the year ended the 28th February last, the quantity of gold obtained was 2,166oz. 6dwt., representing a value of about £8,665, and the expenditure in wages at the mine and in explosives amounted to £5,255 15s. 3d.; to this would have to be added the cost of maintaining plant, water-races, and office expenses. The cost of explosives alone in breaking up the cement for the year was £613 9s. 10d. The number of cubic yards of material sluiced for the year was 161,841·3, which gave an average value of 6·42 grains of gold, or 1s. 0.85d. per cubic yard.

The following statement shows the height and quantity of material lifted for the year ending 25th February last:—

No. of Elevator.	Number of Hours Sluicing.	Number of Cubic Yards Sluiced.	Gold Obtained.	Height of Material Lifted.	Head of Water on Jet.	Diameter of Jet.	Diameter of Liner on Elevating Pipe.	Number of Sluice-heads used for Lifting.	Number of Sluice-heads for Sluicing.	Number of Cubic Yards lifted per Hour.	Gold Obtained per Hour.
	Hours.		Oz.	Ft.	Ft.	In.	In.				Dwt. gr.
1	2,179·5	58,107·9	567·65	62·5	400·5	3¼	7½	10	8·75	26·66	5 2·6
2	1,816·5	60,550·0	642·70	63·5	408·0	3¼	7½	12·5	11·25	33·30	7 1·9
2A	1,295·5	43,183·4	955·95	63·5	408·0	3¼	7½	12·5	7·5	16·66	7 9·0
2B	1,295·5			42·0	354·0	2⅝	7½	7·5			
Total	6,587	161,841·3	2,166·30	..	..	..	..	..	..	24·40	6 13·9

* "Map of New Zealand, showing the Principal Faults and Earthquake Rents": Geological Reports, 1890–91.

To take the total number of hours that the whole of the elevators have been working, it equals one elevator being worked continuously for 274·4 days, and taking the quantity of material lifted, with the number of sluice-heads of water used on elevating-jets, it equals $\frac{76{\cdot}62}{41{\cdot}5}=1{\cdot}846$ cubic yards for every sluice-head used in jet; but, as the No. 2 elevator is only lifting the material from No. 2B, this should not be taken into the calculation; it would, therefore, be $\frac{76{\cdot}62}{29{\cdot}5}=2{\cdot}6$ cubic yards for every sluice-head of water used in elevating-jets. It will be seen, however, that the height that the material is lifted is 62·5 feet by No. 1 elevator, which is equal to raising the material 15·5 per cent. of the hydraulic head of the water; and as the No. 2 elevator lifts 63·5ft. with 408ft. of head, the percentage is the same in both cases.

It is quite a pleasure to inspect this company's workings, as all the plant is kept in good working order, and the manager is always ready and willing to afford any information in regard to the quantity of material that can be operated on by elevating-plants of this description, which are of modern invention, and can be used with great success wherever a good head and supply of water can be obtained to work ground by hydraulic sluicing, where there is not sufficient fall and dump for tailings by the ordinary method. There are fifty men employed on this company's works.

Local Industry Company.—This company is still working the bed of Gabriel's Gully with success. Its operations are confined to the side of the gully next to the range between Gabriel's and Weatherstone's. This side of the gully was not worked by either the Gabriel's Gully Sluicing Company or by the Blue Spur Company, so that there is a large amount of ground still left if the whole of it prove payable for working, between the present face and the place where the run of gold in the gully cut out, opposite the Blue Spur Company's workings.

Weatherstone's.

The area of breccia-conglomerates at Weatherstone's is greater than that of the Blue Spur, and the thickness of the deposit (at least 500ft.) is also greater. The gravels, however, do not appear to be so rich in gold as at the Blue Spur, and, as a consequence, not more than one or two claims are being worked in the undisturbed beds, the other parties working within this area confining their attention to ground that has already been worked, or to the superficial gravels that constitute a re-wash of the breccia-conglomerates.

The Weatherstone Basin, like that of the Blue Spur, is bounded to the eastward by the principal fault or slide already described, while the lower beds of the breccia-conglomerate crops out on the hill slopes to the north-west and west, and, dipping south-east into the deep ground of the flat, appear to suddenly terminate, by the up-rising of the schist rocks to the south and east.

Very little work is now being done in this locality. A few years ago a company was working the same description of brecciated material which occurs at the Blue Spur, but the method of working this deposit here was to slow too make it a payable venture. Nevertheless, taking the average yield of the ground worked, it would be fully as rich as the Blue Spur deposit. The Prospecting Association sunk a shaft, and did considerable work in trying to pick up the same run of ground as the company referred to were working, but were not successful in their operations.

Waitahuna.

During the early part of the year, Mr. Perry had a dredging-plant on the Waitahuna River, opposite the Town of Havelock. This, however, dealt only with the more superficial deposits. Clays, lignites, and quartz-drifts underlie the modern river-gravels over Waitahuna Flat, but the lower beds of these have never been prospected. In the lower grounds this would be a work of some difficulty, on account of the presence of water in greater quantity than could be easily dealt with; but towards the margins of the basin it might be possible to reach bottom. In the meantime nothing is being done towards the prospecting of these beds.

The principal work carried on in this neighbourhood is being prosecuted in connection with a similar deposit to that of the Blue Spur, situated in Waitahuna Gully, or the valley of the first creek of any consequence joining the Waitahuna from the south, in following the river upwards from the main road to Lawrence. Two large sluicing-claims have been worked in this valley, both of them dealing with the breccia-conglomerate deposit. The most northerly of these, on the west side of the valley, is still at work; but that at the upper end of the valley has for the present ceased operations, the water-power of the company now being used in connection with an elevating plant, dealing with part of the flat opposite the post-office.

Waipori.

Work here is chiefly confined to the flats along the river-beds, Lammerlaw Creek, and the points of some of the spurs on the north side of the valley above the township. A heavy, rough wash occurs south of the township, at the source of Pioneer Creek. Some time ago a claim was opened out in this deposit, but it is not now working. The greater part of the deposit in the low grounds consists of quartz-gravel, with beds of clay and lignite. It is commonly understood amongst the miners that there are two separate and distinct formations of quartz-drift, and this seems to be supported by the upper gold-bearing gravels resting on a lower, that may be quartz-drift, clay, or lignite, and of which the higher beds of quartz-drift has not been proved auriferous to any extent. The hydraulic elevator at work in the mouth of Lammerlaw Creek, in having worked to the bed-rock, does not clearly show any distinction between the upper and lower parts of the drift-deposit, and the works at that place are now well advanced into the broader valley of the Waipori.

It is certainly remarkable, as noted by Mr. McKay, that within the Upper Waipori Valley the quartz-drifts are confined to the low grounds of the valley itself, and never appear on the high lands adjoining, as is almost always the case in other parts of the Otago district.

There are a considerable number of miners employed in different places on the field, but the largest mining operations outside the dredging companies are carried on by the Deep Level Company. This company, some years ago, purchased a portion of the ground they now hold from Messrs. O'Brien and party; but the gut or slide where rich auriferous wash-drift was worked by O'Brien is long since worked out, and this lead has been traced into the flat. Their present paddock, taken out on the flat, is about 300ft. long by 150ft wide at the top, but narrowing down greatly at the bottom. The manager states that the ground, as a rule, was very poor, and it was hard work to make ends meet. The balance-sheet for the year ending the 23rd January last showed the called-up capital to be £11,730, and money borrowed on mortgage, £2,756 15s. The wages for the year amounted to £1,002 13s. 3d.; management, directors' fees, &c., £153 15s.; interest, £364 5s. 8d.; materials, £216 14s.; and other charges, £114 5s.; rent of water, £78, making a total of £1,929 12s. 11d.; and the value of the gold obtained for the same period was £1,985 17s. The wash-drift is of a quartz-grit formation, but from the appearance of the bottom at the time of my visit, it will be difficult to follow the run of ground far into the flat, where the gold has hitherto been obtained.

The most of the individual miners are working in the gullies, and on the terraces lower down the river than the township, and on the whole they are making fair wages. There is no rich ground, but by steady work and a supply of water any one can make small wages on this field. There are about a couple of months in midwinter when very little work can be done, owing to the frost, which prevents sluicing operations from being carried on.

Clutha Valley.

There has been very little new ground opened in the Clutha Valley last year; neither can it be expected so long as the present claims are being worked. All the available water-rights are taken up and held by the present mining companies, and, although there is a large quantity of gold still in this valley, the ground is not sufficiently rich to pay for working it by any other method than by sluicing, and, as far as the flat land in this valley is concerned, very little of it can be washed away by ordinary sluicing operations. It is only the top stuff that can be run away from the terraces close alongside the river, the bottom material having all to be elevated. Some of the claims, such as Eddie and Kirkpatrick's, at the Horseshoe Bend, can be worked level-free, there being plenty of fall for the tailings; but very few of the others, except some of those on the opposite side of the river from Roxburgh, can be worked in the same way; and even the claims at Roxburgh cannot be worked on the bottom near the side of the river; it is only where the workings are getting a considerable way back that the bottom is got, and then the fall in the tail-races becomes so little that it would pay the owners better if they had a good supply of water with sufficient head to elevate the bottom portion of the ground with hydraulic elevators. This valley will continue to yield gold for several generations, and, probably, by improved methods of working, our posterity may make ground which we are now leaving as valueless pay for working.

Island Block Company.—This company has, during the past year, been successful in carrying on its operations. For a considerable time it was working very poor ground, having lost the run or track of the gold-bearing drifts. A short time previous to the publication of the last annual report, the run of auriferous drift was again struck, and since then the operations have been carried on, following this run, which has no doubt been at one time the bed of one of the channels of the Clutha River; but the flat here is a considerable width, and, possibly, the river has flowed down in more than one channel. Looking at the topographical nature of the country, and the point where the river has cut out to flow in its present course, the high range on the south-western side comes round, forming the segment of a large circle, and it is a well-known fact that the tendency of flowing water is to follow round the inside of a bend and scour the channel deeper there than elsewhere. Taking this into consideration, there is a possibility of the main channel of the river being found under the present road; but the remains are still visible of a large slip that has taken place from the side of the range, about half-way up the flat, and probably this filled up the ancient river-bed and caused the river to cut out a new channel, and in that case it would be much nearer the island, and account for the run of rich wash-drift now being worked.

There is a great depth of rich alluvial soil on this flat, which has hitherto been a source of trouble to break down and send up in the elevator. Recently the manager, Mr. C. E. Rawlins, has constructed a drag, to work by water-power, to remove the soil and clay and stack it on the surface of ground where the run of gold-bearing drift does not go under. Poppet-heads have been erected 24ft. high, with pulleys on top, over which wire ropes will work to haul the drags. It is expected that the drags will excavate and haul up material at the rate of one ton per minute. This machine is also to be used for bringing down the material to the elevator, and the manager is in hopes that he will be able to do the work for about one-tenth of the present cost.

During last year about 2,000ozs. gold have been obtained, and about thirty men have been employed. The manager finds that the ground is getting better as he goes up the flat, and, with his improved method of working, the next year's returns ought to leave a handsome profit to the shareholders. The manager estimates that he can send away through two elevators about 12,000 tons of material weekly, which is equal to about 50 tons per hour, taking stoppages for repairs into consideration. It will take a life-time to work out this ground, and if even moderate returns be got, the undertaking should prove a profitable investment for the capital expended.

Island Block Extended.—This company have recently been very successful in carrying on their operations. The workings are extending into the flat towards the terrace, and a good run of wash-drift has been struck some distance back from the river, and it has evidently been the course of the river in former times. In working on this run of ground, 250oz. of gold was obtained for twenty days' work. A paddock has been put down some distance higher up the flat, where the present hydraulic-sluicing operations are carried on, and about the same distance back from the mine, which

shows the bottom to be dipping towards the terrace, thereby indicating that the river had at one time been flowing close to the terrace. It is not, however, to be expected that gold will be found continuous even amongst the gravel of the former channels: in some places it will be found in rich patches, while in other places in the river-bed gravel, scarcely any gold will be found. The same thing takes place in the present river-beds; in places the gold has been completely scoured out, but it is generally found on bars and rough bottoms.

This company is elevating the material to a height of nearly 70ft. The hydraulic head on their pipes is 800ft.; but, according to the pressure-gauge at the bottom, it only registers 270lb. to the square inch when the water is going through the nozzle, which is equal to a hydrostatic head of 622ft., which shows the nozzle used to be too large for the supply of water with this pressure, or else it means a loss of 178ft. head by friction.

Roxburgh.

The claims on the opposite side of the river from Roxburgh are doing fairly well. The ground is getting washed away alongside the banks of the river, and the workings are now getting well back into the flat. The ground, however, is not so rich as it was close alongside the river; nevertheless, there is another deep run of ground going through the flat, in which good prospects can be got.

Roxburgh Amalgamated Company.—This company stripped a large area of ground by sluicing off the top material down to such a depth as the fall for the tail-races and sluices into the river would admit, and during the last year they have been working the bottom portion of the ground by hydraulic elevating. The whole of the stripped ground is not yet all worked, but the returns from the operations, although payable for working, have not come up to expectations. The workings are now back about 20 chains from the river, and payable gold got from the whole of the distance: two distinct runs of gold have been crossed, and the manager expects to get a deep run of ground still further back, where, probably, the river had flowed at one time, skirting round the foot of the range, and coming into the gorge at the junction of the Teviot River. The water-supply is taken from the Teviot River, where a concrete weir is constructed in the mouth of the gorge, leading out of the Dismal Swamp. This weir has been raised another 6ft. 6in. last year, with stone and cement, the Roxburgh Amalgamated Company paying two-thirds of the cost, and Ewing and McConochie, who purchased the plant and claim belonging to the Hercules No. 2 Company, is to pay the other third of the cost. This could be made, with very little expenditure, one of the best water-supplies in Otago, as the Dismal Swamp is a large area of flat land, where water could be dammed back at the mouth of the gorge, and thus insure a never-failing supply. There are thirty men employed by this company. Taking the balance-sheet of this company for the year ended the 30th of April last, the value of the gold obtained for the year amounted to £5,420 1s. 7d., while the whole expenditure for the same period was £3,649 18s. 1d., thus leaving a net profit on the workings of £1,770 3s. 6d. for the year.

Some of the private claims higher up the flat than the Roxburgh Amalgamated Company have been doing very well. It is said that the shareholders in one of them has averaged about £10 a week when at work.

Hercules No. 1 and No. 2 Companies.—These companies' workings are on a flat about one and a-half miles lower down the valley than the Roxburgh Amalgamated Company's ground. The Hercules No. 1 Company took up the whole of this flat, and, after working a portion of it for some months, sold the one-half of it to another company, which was termed the Hercules No. 2. Both of these companies' ground was payable for working alongside the edge of the river; but on getting back into the flat, the ground got poorer, and did not return a profit on the company's operations. There is a large number of boulders and big stones in the drift, which entails a good deal of extra expense in removing and stacking. The Hercules No. 1 Company paid extremely well the first two years after it commenced operations, the shareholders getting back the most of the capital invested, if not the whole of it; but of late years it has had a struggle to make ends meet. There is always the chance of another deep run of ground close to the foot of the range; but the workings in the No. 1 Company's ground are now getting a good distance back from the river, and no sign of this has yet been met with. According to the last balance-sheet presented to the annual meeting of shareholders, the value of the gold obtained for the year was £2,970 4s. 3d., and the expenditure in connection with the working was £2,000 18s. 10d., but the net profit for the past year was only £69 5s. 5d., as there were other expenses in connection with the office, &c.

The Hercules No. 2 Company could not make the ground pay for working, and it went into liquidation some eighteen months ago, and the property and plant was purchased by Messrs. Ewing and McConochie, who intended to remove the plant to their claim at Tinker's; but before doing so they agreed to give the ground a trial, with the result that sluicing operations have been carried on ever since. For some time the yield of gold did not pay the expense of working; but as they got nearer the foot of the range which projects to the edge of the river at the lower end of their ground, better prospects were obtained, and recently the workings are being carried on at a profit.

Spear-grass Flat.

There are three sluicing claims working in the small gully and flat at the back of Mr. Kemp's store and hotel; this gully was all worked by paddocking in the early days, and some portions of it were ground-sluiced with a small supply of water, but the natural fall is not sufficient to carry away the tailings. About three years ago Hesson and Simmonds took up some ground in this locality, and erected a hydraulic elevating plant, and since then they purchased the water rights belonging to the Commissioner's Flat Company, which went into liquidation, and have constructed a water-race from Coal Creek to the ground. The claim is said to be paying very well. The material is lifted for about 20ft.

Messrs. Ewing and McConochie have also a claim in this locality, which they are working by hydraulic elevating, the material being lifted about 16ft. They were formerly working ground in private property belonging to Mr. Butler, but as a satisfactory arrangement could not be made with the proprietor for future working, they purchased some ground in the gully below where Messrs. Hesson and Simmonds' claim is situated for £450, and at the time of my visit were engaged in washing up a portion of the sluiced ground. From the prospects shown me, taken from the wash-drift, this ground ought to pay very well for working. The supply of water is, however, limited; they have to rent a supply-race belonging to Dr. Hyde, which came from the Old Man Range. The ground is shallow, it being only about from 6ft. to 8ft. in depth, and the gold is confined to a thin layer of wash-drift on the bed-rock, which is of a very soft nature, and easily cleaned up with the sluicing-nozzle by blowing the whole of the material with the water forward to the elevator.

Mount Ida.

This is a large district (which includes Naseby, Kyeburn, Hamilton, Blackstone Hill, and St. Bathans), and one where the gold-workings are carried on by hydraulic sluicing, with the exception of three or four men, who are engaged in working quartz lodes. There is a large area of auriferous country in this district; but the number of claims that can be worked is limited by the quantity of water that can be brought on to command the ground. The whole of the small creeks and tributaries that are near the places where gold-workings are situate are utilised and brought in to work the ground; but in many parts of the district the small drop of water available is totally inadequate to carry on mining operations to the best advantage.

Naseby.

The last season being exceptionally wet, and the alterations which were made in the Mount Ida Water-race, has given the miners a steady and liberal supply of water, and they have done fairly well; still, at the same time, the ground is very poor, and, it being in most parts very shallow, the miners either have not the means, or they do not see their way, to place an efficient plant on the ground. As year by year passes by, improvements are, however, made in the methods of works, and, although these progress slowly, they are steadily gaining ground, and the miners find that with a good plant they can make their claims pay much better.

At Speck Gully there are seven or eight claims being worked, and, of these, the holders of six of them are using water from the Mount Ida Water-race. One of the claims is held by Mason and Donnelly, who have rented Hit-or-Miss Water-race, which is brought in at the highest level on the field, and these men may be said to have the best plant for hydraulic sluicing on the field. Their main line of pipes are 11in. in diameter, and, having a fair supply of water and a considerable head with moderately shallow ground, a large area is washed away in twelve months. These men have gold-saving tables at the end of their sluice, which, they find, saves a large percentage of the gold which otherwise would be lost. The same party have a claim in the bottom of this gully, which they were working a few years ago with a hydraulic elevator; but they have done no work here for a long time, as they find that the shallow ground on the face of the range pays them better.

Home Gully.—The principal working in this gully is carried on by Chinese. The most of the land in this gully is freehold, and some of the Chinese have purchased small portions of Mr. Joseph Creighton's property, at the rate of £20 per acre. There is, however, very little fall for tailings in this gully, and therefore mining operations are limited.

Hogburn, or Main Gully.—There are a number of claims being worked into the Main Gully, and some of them have paid well for working. The Extended and Dead Level Companies have done very well last year. The Dead Level Company are working the bed of the gully, and elevating the material about 16ft., with water from the Undaunted Water-race. A continuous supply flows into a dam which the company has constructed at the head of Home Gully, and, by having this dam, a fair supply of water is obtained for about eight hours per day to work their claim.

Roach's Gully.—This is a small gully in the Township of Naseby which had been worked in the early days, but no one for many years ever thought of prospecting it any further. About two years ago this ground was taken up by Messrs. Guffie and Indor, and a hydraulic elevating plant put on the ground. The claim is now nearly worked out, but, during my recent visit here, one of the shareholders informed me that it had paid them £100 per month for the time they had been at work, clear of all expenses.

Wet Gully.—There are four claims being worked in this gully, but, as far as can be ascertained, the ground is far from being rich.

Enterprise Terrace.—There are four parties of miners at work, and if these claims can be made to pay there is work in this locality for many years. The ground is from 30ft. to 50ft. in depth, and with a good head of water ought to be made to pay very well for working. The quantity of water used is, however, very small. The miners in this locality have not been accustomed to use a large head, for the reason that the water has not hitherto been available.

Some new ground was opened up last year by Messrs. Wheeler and Fennessy Brothers at the Idaburn, on the upper side of the Mount Ida Water-race. This party purchased the right of two heads of water, which Perry and party held from the Idaburn, for £150, and got the right to lift one head instead of two, and shift the head of their race about four miles higher up the creek than where the water was originally lifted. This ground was prospected by Mr. Wheeler during the time repairs were being made to the Mount Ida Race, and, as far as can be ascertained, the ground is paying very well. Another claim has recently been taken up in this locality, but there will be a difficulty in getting water to work it.

There is a considerable area of auriferous ground between this and Hill's Creek. Gold was got many years ago at the Little Idaburn, below the Mount Ida Race, and there is a great probability

of some good claims being found in this locality if the ground was prospected. This is on the line of the run of the quartz drift, or what the miners in the locality term the granite wash. This drift extends up to the head of the Mount Ida Race, it can be seen in patches here and there, but very little prospecting has ever been done. If people would prospect this part of the country in the spring of the year there is always a good supply of water to be got from the Mount Ida Race, as at this season of the year the water in the several creeks above Pearce's Gorge are generally cut off up to about Christmas, and, therefore, the water is running to waste, and could be given to anyone who wished to carry on prospecting operations to test the ground.

Mount Buster.

The auriferous deposits at this place still continue to yield good paying returns to those engaged in working them. There is a considerable area of quartz drift favourably situated as regards actual sluicing and the disposal of the tailings; but, with respect to water-supply and the length of the season during which work can be carried on, the conditions are not so favourable.

The water-supply is limited and dependent on the amount of snow that falls upon the higher ranges during the winter and spring months; consequently, the period during which work can be carried on depends upon how early work can be resumed in the spring, all operations being suspended during the late autumn and winter months.

The auriferous deposit consists of sands and coarser drifts which are almost pure quartz. The lower part of the deposit is often of a coarser description, containing boulders of quartz up to 6in. in diameter. For the most part, the bedding is nearly horizontal, and the area covered by the quartz drift varies in breadth up to fully half a mile, and has a linear extenison north—south of about four miles. The height above sea-level is approximately 4,000ft. The auriferous character of this deposit has been sufficiently commented upon in previous reports. All the available water is now in use, and at the present rate of working very many years must elapse before even the richer and better-paying parts of the deposit will have been worked away.

The great height of this deposit above sea-level might lead to the assumption that it belongs to a different formation than that to which belongs the quartz drifts of Livingstone and the eastern lower slopes of the Kakanui Mountains, or even those deposits of a like character that border the Maniototo Basin and appear along the margins of Ida, Poolburn, and the Manuherikia Valleys. Mr. McKay endeavours to prove that the quartz drifts of Mount Buster are of the age of the drifts at Livingstone, which are of Cretaceous or Lower Cretaceo-tertiary age, and that the beds in the two localities were once a continuous deposit, which in latter geological periods have been sundered and displaced vertically till the denuded fragments of the formation appear, some of them at or near sea-level, whilst others, like that on Mount Buster, reach to or exceed a height of fully 4,000ft. above the sea.

The displacements requisite to account for the presence of different parts of the same formation at such different heights above the sea are marked along certain lines of fracture, one of which, as described in Mr. McKay's report, runs along the eastern border of the Maniototo Plain, and to the northward crosses the saddle at Clark's into the Waitaki watershed. The amount of vertical displacement along this line is least in the north, and much greater toward the south, till it is intersected by another line of fracture, called the Waihemo Fault, beyond which intersection the Kyeburn Fault has not been clearly traced. The result is that along that part of the line which has been traced there is a difference of fully 2,000ft. in the levels at which the quartz drifts appear at different places along the line.

Upper Kyeburn.

A small patch of quartz drift is reported as occurring in the valley of the Kyeburn, about three miles above the upper township; but though this may be, it is hardly likely that such deposits ever extended east through the Maraewhenua Pass to make connection with the like deposits at Livingstone. Prior to the upheaval of the area out of the rocks, of which were sculptured the mountain ranges separating the Maniototo Plain from the Waitaki Valley, there may have been, and probably was, a connection and continuity of the quartz drifts of the now distinctly separated districts, and such fragments as are now met with in the intermediate mountain-space must be considered as having been so preserved, in spite of the enormous waste and removal of the rocks of the mountain-region in which these grits occur as the youngest rocks, other than gravels, &c., in process of translation to lower levels. Below the Upper Kyeburn Township the quartz grits, &c., show in the banks of the stream, and strike along the western base of the Mount Pisgah Range. As described by Mr. McKay, they would appear to form a double series; but, as neither of these appear to be worked for gold at this place, they are of less interest than otherwise they would have been.

Gold-workings at the Upper Kyeburn are confined to the recent alluvial deposits of the main stream and some of its tributaries, and to beds of older Pliocene age, consisting of heavy sandstone gravels ("Maori bottom") that form the southern part of the range of hills east of the Little Kyeburn, and separated from Kyeburn Peak by a valley depression that leads north to the foot of the steep slope by which the upper levels of Clark's and Mount Buster are gained.

This range, running along the east side of the Little Kyeburn Valley, seems to contain a variety of different deposits, the relations of which to each other are as yet improperly understood. At the southern end it is composed of the gravels which in this district are usually called "Maori bottom"—"old-man bottom" of the West Coast. In the middle part, at low levels along the banks of the creek, are stratified sands of a bluish-gray colour, containing ordinary concretionary-cement stones, while the higher part of this division of the range is strewn with immense numbers of huge blocks of quartz-grit cement, leading to the belief that the auriferous quartz drifts must form no inconsiderable portion of the whole. The auriferous quartz drifts, however, appear to be absent, and the marvel is whence came such an abundance of the cement blocks derived from that formation.

The northern end of the range shows the presence of a schistose slaty breccia, similar in character to that seen at Tinker's, Drybread, and Criffel face, in the Cardrona Valley.

Extensive sluicing is being carried on at the western base of Kyeburn Peak, a large claim being there situated directly on the line that would connect the workings at Mount Buster with those at the Upper Kyeburn Township. Opposite this, and about one mile and a half distant, another sluicing claim is being worked, in the upper part of the Little Kyeburn, a little below where the road begins to ascend Mount Buster. So far as could be ascertained, the larger claims, having at command a good supply of water, yield satisfactory returns.

Mr. McKay, in his last year explorations, in tracing the quartz drift from Mount Buster, Kyeburn, and the Maniototo Plains, found the drift exposed at the surface on the road leading from the Taieri Bridge to Ewe Burn and Naseby. Here, Mr McKay states, the drift lies at low angles, and spreads over a considerable breadth of country. To the south-east they pass under the basaltic sheet developed in the middle of the Maniototo Plain, while to the north-west they are overlain by the recent sandstone gravels of Ewe Burn Creek. Along the double ridge striking in the direction of Ewe Burn Schoolhouse, they extend four or five miles, and these beds are so disposed and situated that they might be prospected to very considerable depths without encountering water. The bore-hole put down at the Ewe Burn, for the purpose of proving the existence of artesian water, in its deeper part passed through these beds, and gold was found in the material brought up from a considerable depth in this bore-hole. Much lower beds would be met with at the surface within a mile or so of the Taieri Bridge. This area is well worth prospecting, even though the quartz drifts could not be passed though or bottomed, because gold in paying quantities does occur at different horizons in these quartz-drifts. No prospecting has been done over this area other than one or two shallow holes put down to prove the rewash deposit on the sides of the low spurs within a short distance of the junction of the Hog Burn with the Taieri.

Little gold has ever been obtained from the Ewe Burn Creek bed, but the line of quartz drift traced east from the Wether Burn is returned considerably to the north, and crosses the Ewe Burn Valley in the line of Butcher's Gully, where some workings, now abandoned, have been carried on; also in the bed of the Ewe Burn, at about where the quartz drifts cross, gold-workings once were, though no one is working there at present. The rocks of the Mount Ida Range are not gold-bearing, and it is from this source that the recent gravels of the Ewe Burn Valley are supplied: hence their non-auriferous character, except near the point where the line of quartz drift crosses the creek.

Hamilton's.

With an ample water-supply, the whole of the quartz drift in the lagoon-basin at Hamilton's would, ere this, have been washed away; but two or three parties, with a limited supply of water, alone are working the ground. The sweeping-out of the lagoon-basin is not likely to be accomplished for many years to come. The smaller area of quartz drift at the Shepherd's Hut has been largely, and, lately, more energetically worked than the same deposit at Hamilton's. At both places the great drawback is the lack of water, which is scarce so soon as the snow has melted off the northern part of the Rock and Pillar Range, which is not high enough to retain snow longer than the middle of December.

Between Hamilton's and the Taieri River, above the Taieri Lake, the slope of the range is covered by a thick sheet of basaltic rock, underneath which there are white clays, underlain by quartz drifts, that outcrop to the surface at the north-west limits of the volcanic sheet, and also in the south-west or up-hill side of this area. This latter line of outcrop has been worked as far as could be done on account of water, and, as reported to Mr. McKay, good prospects of gold were still to be had when the works along this line were abandoned.

There should be no difficulty in proving these quartz drifts at many places along the north-west line of outcrop, nor, considering that from the Taieri River to Hamilton's there is a rise of 800ft., should there be the least difficulty in draining by audits the quartz drifts under the basalt sheet.

Considering that Hamilton's has yielded a very large amount of gold since it was opened, and that the grits under the basalt have been worked along their south-west outcrop, it is somewhat surprising that nothing has been done to prove these beds where they underly the volcanic rock, more especially since, according to Mr. McKay's description, and the section of the beds he shows, this could very easily be done.

The volcanic rocks of Hamilton's stretch across the Taieri, and form a ridge of low hills between the Taieri Lake and the lower part of the Hogburn Valley. On the north-east side of the Taieri the volcanic beds dip to the south-east, and thus the underlying white clays and quartz grits tend to appear, and the latter do actually appear in the low ridges between the lower courses of the Hogburn and the Eweburn before these streams make junction with the Taieri.

This is a part of the district which has never been prospected, apparently because the surface indications are that the ground is likely to be very deep to the auriferous stratum; but it would appear that, since the quartz drifts over a considerable area are actually at the surface, the depth to sink may not be so great after all.

For the present, however, there is scope enough for prospecting under the basalt sheet of Hamilton's, where the bottom can be reached and the beds proved as to their auriferous character.

Hyde.

Mining at Hyde is in a very backward state at the present time. A very limited water-supply is available, and those holding the bulk of the water are engaged in sluicing the bed of Hyde Creek, near the Taieri, and thus bringing up a low-level tail-race, by means of which, eventually,

they will be enabled to deal with the quartz drifts under and at the back of the township, part of which will prove to be virgin ground, likely to yield good returns. At Hyde gold was first found in the rough creek-wash within the upper part of the present township, but on the rush taking place during January, 1864, gold was found in the quartz drifts on each side of the gully, and in some particular spots very rich returns were obtained from the quartz drifts. The creek rubble, up to a certain point, also paid fair wages, but beyond the upper limit of the quartz drift on the spurs on both sides the creek gravels became poorer, and shortly ceased to yield payable gold. This pointed to the quartz drifts as the probable source of the gold obtained from the wash of the creek-bed, a fact which the miners at first were slow to apprehend, but which latterly has been fully appreciated, if not quite understood. The quartz drifts resting on the slope of the range, and having a general dip in the direction of the Taieri River proved very rich in gold at the point where the lowest beds made junction with the schists in the bed of the creek. From the creek-bed the rich lower stratum was traced through the spur to the south-west to the next gully in that direction, and was worked first by driving out the wash, and afterwards by ground-sluicing as far to the dip as the richness of the material was sufficient to yield payable returns, or water would admit of.

In working this old ground on a large scale, and with an abundant water-supply, there is a probability of its being made to pay, while there are areas of ground as yet untouched that may prove comparatively rich in gold.

At the Four-mile (Fullerton's) there were worked some very rich patches of quartz drift, and by way of Mareburn to Highlay Hill, and more to the south in Station Hill, there are areas of quartz drift that, were a better supply of water available, should be made to pay well.

Blackstone Hill.

There are only about seven parties of miners working in this locality, and from all the information that can be obtained as to the yield of gold, the ground is not rich; it is only when a large quantity can be washed away that it can be made to pay decent wages. Mr. R. Johnstone has been for the last two or three years carrying in a prospecting-cut, and it will take him yet about another year before he will get into the ground where he expects to find gold. Mr. C. Rose has about one of the best claims in this locality; he has been working here for a number of years, carrying on his operations energetically and continuously, with the exception of about two months in winter, when the ground is in a frozen condition and cannot be worked.

The Blackstone Hill Goldmining Company have completed about ten miles of their water-race, and a tail-race is in course of construction, where sluicing operations are to be commenced. The water-race conveys at present about twelve sluice-heads of water, but this quantity will soon be increased to about seventeen sluice-heads, which will give a very good supply to carry on sluicing operations. The company intend to extend this water-race along the face of the range to Black's. This will, however, be a costly undertaking, and one that is not likely to be an accomplished fact for many years to come. There is no doubt a large quantity of gold in the surface-drifts about Blackstone Hill, but this water-race is not at a sufficient elevation to command much of the ground. The only water that could be brought on to command this ground is that from the race the Government purchased from the liquidator of R. Johnstone's estate. The Blackstone Hill Company are said, however, to have a large area of ground that will pay fairly for working with a good water-supply.

There is a large area of auriferous country comprised in the slopes of Blackstone Hill and Home Hills. The ground is mostly shallow and patchy, and a local knowledge is essential for much success in finding the small patches of payable ground. Two or three small parties have, however, worked in the same localities for many years, and occasionally do very well. The Blackstone Hill Water-race Company have completed their water-race from the Manuherikia to Johnstone's Gully, and are now engaged in constructing a tail-race to their claim there. They intend to work this locality for some time before carrying the race farther towards Poolburn and Ophir. They have prospected a large area in Johnstone's Gully, and found gold they consider will pay them well with the large and constant supply of water they are able to bring to bear upon it. The pressure is not good, only about 80ft., but the ground is easily broken up.

Marionburn and Upper Manuherikia.

A long line of quartz drift runs along the south-western base of the Mount Ida and Hawkdun Ranges, from the gorge of the Wetherburn to near the head of the Mount Ida Water-race. Along this line, the quartz drift is of the same age as those of St. Bathan's and Vinegar Hill, which are richly auriferous. The beds along the base of the Hawkdun Mountains have not been sufficiently prospected to show whether or not the gold they contain would pay for working the gravels. Towards the south-western end of the line in Gorge Creek and the upper part of the south branch of Idaburn, perhaps in the Wetherburn also, the beds at places are likely to pay for working.

A party has set in at Gorge Creek, but hitherto they have been working the rough creek-wash, enriched with gold from the quartz drifts which forms a ridge of hills immediately at the back of the ground being worked.

This, as has been pointed out, is the usual process by which gold is discovered in the quartz drifts. The quartz drifts at the place being auriferous, these, on being denuded, yield a portion of the gold they contain. The quartz drift being lighter, and the greater bulk of it of smaller size than the ordinary rubble in the creek-bed or other channel carrying forward the proceeds of denudation, the gold is detained amongst the coarser material, and so parts company from the quartz drift with which it had been so long associated.

The working of such a creek-bed as that which has collected gold in the manner above described necessarily leads to the discovery of gold in the quartz drifts that lie higher up the valley. Special prospecting in the drifts of this vicinity has shown that they are auriferous, and would pay to work with a plentiful supply of water

Further to the north-west beyond Marionburn, and on the eastern slopes of the Hawkdun Home Hills, some prospecting has been done, and a little gold obtained, principally from the gorge of Marionburn, but beyond this to near the source of the Manuherikia the beds are practically not prospected. At one point, near the head of the water-race, gold was found a few years ago, and a rush took place, principally from St. Bathan's. After some work had been done, it was discovered that the gold was not sufficient to pay for working a deposit of drift situated as at this locality it was.

There can be no doubt that it is highly desirable that this line of quartz drift should be sufficiently prospected, which at the present time has not been done.

St. Bathan's.

This is one of the most important mining localities in Central Otago. The material worked within the St. Bathan's Basin is wholly quartz drift, the original surface-wash of the small creek running through it having been turned over and got rid of during the early days of the rush to this place.

The principal gold stratum lies towards, but not close to, the bottom of the deposit, and trends a little to the west of north, dipping at varying but moderate angles, except in the southern part to the west-south-west. The principal gold-bearing band has been worked from the surface to a depth scarcely now to be exactly determined, but considerably more than 100ft.

Mr. John Ewing's elevating plant raises the material to a height of 110ft. in three lifts of 46ft., 40ft., and 34ft. respectively, and at the bottom of his workings there seems to be no diminution in the quantity of gold amongst the drift. At the time of my visit a large slip had come in, which would take some considerable time to shift, the slip material having all to be elevated.

On three sides the basin is bounded by hard Palæozoic rock, but to the west the quartz drifts are followed by sandstone gravels of younger date—"Maori bottom." Towards the south end of the basin the breadth of exposure of the quartz drifts is much less than in the northern part.

The deposit at St. Bathan's, amongst other deposits of a like character in the Manuherikia and Idaburn Valleys, has been described as the fan-like accumulations of material carried into an old lake by the streams that at first fed it and then eventually filled it up.

Mr. McKay is inclined to challenge this theory, and in a former report it has been pointed out by me that such a theory is inconsistent with the mode of occurrence of the leaf- and clay-beds associated with the quartz drifts of the St. Bathan's Basin. Very clearly the whole series, including the sandstones of the "Maori bottom," have been deposited in a nearly horizontal position, and afterwards raised and tilted by some dynamical force, so as to acquire their present varying dip. It may be admitted that these deposits are of fresh-water origin, and that they have been laid down in one extensive lake, or a series of inland lakes, occupying the area of Central Otago, from Lake Wakatipu to the Kakanui Mountains, and from Lake Wanaka to Moa Flat, but this, or these, are in no sense to be confounded with what are commonly called the "old lake-basins" of Otago, which, though occupying portions of the same area, are of much more recent date, and partly filled with deposits that give no evidence of the disturbing influences that have affected the deposits in the older lake-basins. The limits of the older lake-basins can now no longer be traced. The evidence proving the existence of these is to be found in the deepest valleys and on the highest mountains of the district, and the whole topographical system of physical features under which they existed, and of which they formed a part, appears to have vanished. The obliteration of these former physical features, due to the causes that gave rise to those that succeeded, resulted in the upheaval of the now dominant mountain chains of Central Otago, carrying with them to their highest peaks part of the accumulations that formed on the older lake-bottoms, but also, at the same time, deeply involving other portions along their flank, either by an inversion or by actual fracture and faulting of the strata along certain lines. Thus were formed the independent lake-basins of Lake Wakatipu—formerly extending down the valley of the Kawarau to the junction of the Arrow and the site of the Kawarau Bridge—and the old Wanaka–Hawea lake-basin, extending south to Cromwell and Bannockburn, and ramifying up the Cardrona and Lindis Valleys. Thus, also, were formed the present valleys of the Manuherikia, and the Idaburn and Poolburn Valley, and the depression now forming the Maniototo Basin. Thus, within the area of the older, a new series of lake-basins were formed, several of which are now drained or largely filled up, and are thus spoken of as the "old lake-basins of Interior Otago," and, in this way somewhat confusing ideas respecting the elder of this double series may arise. Speaking of the newer series as the younger Pliocene lake-basins of Otago, the deposits in these are recognised from lacustrine deposits of earlier date by their not being tilted or displaced to different levels, as are the deposits belonging to the older series. It cannot be denied that a right apprehension of the facts relating to this double series of lakes should prove of the greatest use to those engaged in alluvial mining in Central Otago. The general facts have been clearly indicated in Mr. McKay's report, already referred to; but there is also no doubt that a close and careful survey will have to be instituted ere we can hope to reap all the benefits that a full knowledge of this subject may be expected to afford.

John Ewing's Claim.—This is by far the richest claim in the locality, and, strange to say, it ruined its former owners; and, when it was not considered to be of any great value, Mr. Ewing purchased it for £1,100, and spent a considerable amount in getting water and a proper plant to work it, and since then it has given excellent returns. He has obtained, since last winter, 1,000oz. of gold, which represents a value of £4,000, and he expects nearly as much more by the end of June, if not stopped by frost. Various mishaps in the way of slips of ground, and unexpected failures of portions of the plant which is used for the work, have thrown washing-up too far into the winter. Three elevators are now used, the total height elevated being 110ft. Six men employed.

Scandinavian Water-race Company.—Five men have had very poor returns, the total obtained (two years' work) being 320oz. This company combines the selling of water with the working of

ground, otherwise the work of those years would have resulted in a loss. It has much better ground to operate upon, but it will require to be worked by hydraulic elevating.

United M. and E. Company have obtained during the year from their Blue Gully Claim 350oz., and from Surface Hill 100oz. They also sell to Mr. Ewing a considerable amount of the water used by him at Kildare Hill. They had a considerable area of fairly good ground not get-at-able, except by elevating, until the completion of the St. Bathan's Channel.

Muddy Creek Tail-race.—This is owned by the two last-mentioned companies. A portion of the channel washed up recently yielded about 300oz., for an expenditure in cleaning up of £300. Six men employed.

St. Bathan's Water-race Company.—This company's claim is situated at Surface Hill. They have shifted their operations farther north to some new ground, which is expected from appearances, as it is being opened out, to give much better returns than what they have been working for many years past. They have put in gold-saving tables for this ground. The returns from the old ground for the past year gave only small wages. Five men employed.

Eagle and Gray, and P. Tiernan and Company.—These parties are both making fair wages in the same claims they have been working for many years past. The former have nearly all the ground at present level worked, and will soon have to stop, pending the completion of the St. Bathan's channel, or elevate. A few small parties still buy water, and work blocks in the old ground, but the number able to obtain remunerative employment in this way yearly diminishes.

St. Bathan's Channel Company.—The whole of the course of the new channel has now been stripped, and the tail-water from the claims turned on to line of channel. The formation remaining being entirely clay, and all stones being removed, it is anticipated that the tail-water, with the assistance of a large body of flushing-water joining it near head of channel, will do all the cutting required. The company has obtained 300oz., the result, however, of nearly two years' work. Much more was expected, and may yet be got, as a large area of the ground worked is only now in process of being cleaned up. A portion of the upper level channel, which has carried the tailings from all the St. Bathan's claims for over twenty years, was cleaned up in March last. The best informed were greatly deceived at the result, where over a hundred ounces were expected only a fourth of that amount was obtained. This result proves that, to save fine gold escaping from tail-races, special appliances must be employed. Mr. Ewing, the legal manager, is confident that during the time this channel had been working, at least 500oz. have gone through it and been lost that might have been saved on properly constructed tables. Five men employed.

Tinker's.

Many years have passed since this place had one like this for efficient water-supply, and never before have the results been so poor in comparison. The Undaunted Company has worked twice as much ground as usual for little more than half the gold, 800oz. being the total obtained by it for the year. Twelve men employed.

Sugar-pot Company.—This company got 400oz.—the result of nearly two years' work—on the ground known as the Deep Lead, being the old drift formation, with nearly vertical strata, prospected some years ago by Fogarty and party. The ground now treated by the Sugar-pot Company gave nearly 1dwt. per cubic yard; but work was so hampered by accumulations of stones from former surface-workings, and the face obtainable from the company's tail-race was so small, that the ground has little more than paid wages. With good pressure, and a large supply of water, this ground, worked on the hydraulic elevating principle to a depth, say, of 100ft., would give excellent results. Fogarty's prospecting proved the formation to extend, with little difference in prospects, to a depth of 240ft. Six men employed.

Mountain-race Company.—This company's return is 550oz., also for two years' work, and on the "granite-wash" formation. This return is fairly payable, as not many men are employed; and the two years' yield represents less than one year's work, the other being lost in stoppages for want of water. Four men employed.

Simes and Morgan.—Actual yield has not transpired, but it is understood that they have made fair wages. They have shifted from the "granite" formation to a terrace south of Scotchman's Gully, which is said to look fairly well. Four men employed.

Ewing and McConochie.—Since January last they have been at work on the shallow spur south of Smokers' Gully. Ground only averages about 2ft. deep. Have worked 8 acres in four months. Just on the point of washing up. Expect 200oz. Six men employed.

Matakanui Company obtained 350oz. Only at work getting gold till Christmas. Since then engaged constructing another tail-race, very little gold being got in the process. Seven men employed. This company's operations at Drybread, testing the "granite-wash," have not proved very successful so far, although by no means completed. Great bars of pipeclay have been encountered, and the work of cutting through has been very slow. There are several smaller parties at Drybread, Tinker's, and Devonshire. About twenty miners in all have been fairly successful in making wages. At Tinker's, the old runs of ground that have given such highly-payable results for over twenty years are getting worked out. These are situated near the hills, and a considerable extra expenditure will have to be incurred to command ground better than now being worked, known to exist further out from the hills.

Cambrian.—Nothing new to chronicle in this locality. A few parties of miners and a number of fossickers—twenty-five men altogether—make from small to good wages here and in this neighbourhood. Mr. Ewing has all the plant laid ready for working ground on the north side of the old workings in an extensive way, by hydraulic elevating, as soon as the winter is over.

Vinegar Hill.

Since last year some important developments have taken place at this locality. In last year's report* was indicated the probability of there being a deep run of auriferous quartz drift between

* "Goldfields Report," 1893, p. 121.

the then workings in Mr. Ewing's claim and the lower slopes of the high range to the north-west. An improvement in the thickness of the wash-drift at the point of furthest working was then observed, but the amount and great thickness of the overlying banded clays that had to be removed ere the auriferous drifts could be reached threatened not to be less than in the parts of the claim further to the east, and which had proved a great expense in being got rid of; therefore, Mr. Ewing was induced to open out on another part of the area held by him, within which the run of deep ground was expected to be present. This was more to the eastward in the valley flat, on the north side of Vinegar Hill, immediately opposite Mr. Ewing's house.

A run of ground was found here containing a considerable thickness of auriferous wash, which, so far, has proved of a highly paying character. This new discovery is on a continuation to the eastward of the deep ground above indicated, but which has much less cover over it than at the old place. This may prove the prelude to further important discoveries on the same line. It has now to be seen whether or not the line opened out on will extend in breadth north-west to the foot of the range where the auriferous quartz drifts are suddenly terminated at a line of fault extending south-west along the base of the Dunstan Mountains.

Some very rich ground has been worked in this locality, and there is a probability of a connection being made between this place and the ground worked at St. Bathan's. Judging from the green-sands formation which is found in the St. Bathan's Channel Company's ground and that ground in Mr. Ewing's claim with the quartz drift, or what is locally termed "granite-wash," on the north side of this formation, it would seem probable that the quartz drift run of ground would run in a horse-shoe shape towards Vinegar Hill. In a few years more this will be determined beyond doubt.

Mr. Ewing has since October last been chiefly engaged on new ground, north of his former workings, and finds it better than that which he has been previously working, and from which he has suspended operations in the meantime. He has obtained 300oz. so far, and the ground looks much better as he works into it, the formation strongly resembling Kildare Hill, St. Bathan's. It is unfortunate that it should be situated in a hollow, and that everything must be elevated. This discovery was made in ground hitherto considered barren of payable gold; but, from the direction in which the deposit is making, and the method of its occurrence, it was very likely to elude the search of prospectors, and it is not unlikely that an extensive area of ground, highly payable when worked on a large scale, may be opened up. Average number of men employed, ten.

Messrs. Hughes and Morgan obtained 370oz. for seven months' work up to Christmas last, and are now engaged cleaning up a paddock from which they expect as much more. This party's ground looks exceedingly well. Four men.

Watson and party are still getting very good returns in Vinegar Flat, and T. Morgan and party, who are at same place, and McGannon and company, at Two-mile, are making good wages.

Bannockburn.

On the southern bank of the Kawarau River, a short distance above the bridge crossing to Bannockburn Township, a sluicing claim has been started with the intention of working the deep ground which here lies in a gutter beneath the surface of the second terrace, and which has a rib of rock between it and the river.

The tail-race of the claim has been cut through this barrier of rock, but not to a depth sufficient to reach the bottom in the deepest part of the ground intended to be worked. The party working the ground are under the impression that the deep ground will prove to be a distinct old river-chanel leading into the present river-channel at or near the bridge. On this matter, Mr. McKay informs me that he examined the bank of the river from the bridge to the foot of the tail-race from the claim, and is of the opinion that there is no outlet at a lower level in this direction. The deep ground sought to be worked must, therefore, constitute what has been a pool, elbow, or sharp bend in the bed of the river when the Kawarau ran at this level.

This explanation seems to be highly probable, and is the more credible since, if the old channel to a lower level existed, the claim-owners should have set in at the place lower down where this joins the present river-channel. But they have not done so, and, instead, have cut through the rib of rock between the known deep ground and the river. Further down the river-bank a very little inspection should have shown them whether or not the deep ground had an outlet in that direction. In a north-west direction the dividing rib of rock will continue for a short distance and thus confine the gravels seen in the claim between it and the rising reef to the south, or towards Bannockburn. The old rock continues but a short distance to the north-west, the white or blueish-grey clays exposed higher up the river on both banks of it being present in the northern end of the workings, and cut through in the upper part of the tail-race.

There is no reason whatever to doubt the existence of highly payable wash in this claim—rather the contrary. The tail-race does not command the deep ground simply because it has not been cut deep enough; it should have been brought in from the high-flood level of the river at as low a grade as would be effective in working the claim. Even as it is, it will work all the ground except a small area close to where it passes through the rib of hard rock and clay bottom.

A few parties are still working claims into Pipe-clay Gully, but the ground here is getting gradually washed away, and some new ground has been opened a little higher up the flat, which is working into a tail-race constructed by Messrs. Patterson, Bull, and Rooney. The ground in the locality is, however, very poor, and the returns from the most of the claims last year have been smaller than usual, owing to a dispute with the proprietors of the Carrick Water-race as to the reduction in the price of water. This has now been amicably settled, a concession being given by both sides.

Mount Criffel.

Work in this is limited to a few months of the summer season. There is a limited supply of water, and the area of auriferous ground on the northern side of Luggate Burn is somewhat restricted. A more extensive area of the quartz-drift formation occurs on the opposite or south-east side of Luggate Burn, which, at nearly the same level above the sea, extends north and south a distance of between three and four miles, with a breadth varying from 4 chains to 15 chains. This is known as the Fat Boy line of quartz drift, and is now in course of being prospected. The ground is deep, and from the eastward dips towards the west, the beds on that side being suddenly cut off by a line of fault running nearly north and south. These quartz drifts on Mount Criffel and Fat Boy belong to the older series of quartz drifts, such as are met with at Vinegar Hill, St. Bathan's, and Mount Buster, and are to be distinguished from the newer series of breccia-conglomerate and quartz drifts at the base of the "Maori bottom" beds by the presence *in situ* of the quartz-cement stones, which occur as a solid stratum in the St. Bathan's deposit, and on Criffel as a bed broken up, but not removed from the position where it was first formed.

At Mid Run and round the north-eastern slopes of Mount Criffel, some eight or ten parties of miners are at work sluicing another kind of auriferous deposit, consisting mainly of coarse, rubbly gravels that appear to have formed on the shore of an old lake, which, filling the Wanaka-Hawea Basin, also extended down the Clutha Valley as far as Cromwell and the Bannockburn, and stood at a level 1,600ft. above the level of Lake Wanaka at the present time.

There are only a few claims being worked on Mount Criffel. The number of men that can be profitably employed is limited to the quantity of water which is brought on to the field. The water-races are all owned by Halliday and party, and the ground being at so high an elevation a large supply of water cannot be got. Those who are at work here, however, are fairly paid for their labour, but it is only about six months of the year that sluicing operations can be carried on. It is probable that other ground will be opened here when the present claims are worked out, as the water will then be available to work other claims. The yield of gold from this field last season has been about 700oz., and about twenty-seven men were employed.

Cardrona and Criffel Face.

Opposite the Cardrona Township gold has been traced on Criffel Face to a height of 1,200ft. above the level of the valley. The lower slopes of the range consist of the sandstone gravels usually called "Maori bottom." These continue up the slope of the range till, at the height mentioned, they give place to slaty breccia and bands of quartz-gravels intermixed. These latter beds are auriferous. They dip towards the mountain in an irregular manner, and frequently are standing at high angles. The up-hill limit of the formation has not been traced where they are now being worked opposite the township, so that the character of the lower beds there cannot be given. The beds clearly form part of a series involved along a line of fracture or fault which runs the whole length of Criffel Face and ends or reaches the low grounds near Mount Barker, at the mouth of the Cardrona Valley. The prospects appear to be such, that, with a sufficient supply of water brought from the high lands of the upper part of the watershed of the Roaring Meg, there seems little doubt that the ground will pay for working.

The same beds have been prospected at a point some four miles along Criffel Face to the north. The beds at this place are described as dipping at high angles, a quartz drift being seen in direct contact with the wall of schist-rock that limits the formation to the eastward, while on the western side the auriferous quartz and breccia-drifts rest on "Maori bottom."

These beds are of great interest, on account of their being identical with those worked for gold in the deep ground at Tinker's, in the Manuherikia Valley, and in being themselves auriferous.

As yet, too little work has been done to show that a great discovery has been made, and therefore it would be premature to express any opinion as to what the future of Criffel Face as a field for gold-mining will be further than that, like too many other auriferous localities in Central Otago, its progress will depend greatly on the amount of water for sluicing purposes that can be brought on to the ground. In the meantime, there is every encouragement for prospecting the ground at the place opposite the Cardrona Township, and along the line northwards as far as it extends or can be traced.

The mining population at Cardrona continues to be about the same year after year. As one piece of ground gets worked out another is taken up and made to pay for working. Last year a new discovery was made in Criffel Face, where five claims have been taken up, and from all information afforded me they are likely to give good returns for working. The character of the ground worked here is a quartz drift, highly coloured in places with oxide of iron. It crops out on the face of the hill about 1,200ft. above the level of the flat, and seems to follow the line of fault which is clearly seen along the face of the range in places between Mount Barker and Cardrona. The workings are directly opposite the lower Township of Cardrona, and a little over one mile distant. The quartz-drift layer is of considerable thickness. It had not been gone through at the time of my visit, but from its appearance the same layer will be found lying about horizontal on the flat, but it has been tilted up against the face of the slide and turned over slightly on the upper edge. It has the appearance of being identical with the layer of rich gold-bearing wash in Robertson Brothers' claim opposite the upper township; but, be this as it may, there is a similar class of gold got in the drift. This deposit is likely to run along the face for some distance, but the number of claims that can be worked is limited to the water-supply brought on to the ground. Fryar and party and Plimmer and party constructed a water-race from the Roaring Meg Creek, which is said to carry about five sluice-heads of water. The parties using the water have constructed dams on the range so as to conserve the water when they are not at work. Those who are not share-holders in the head-race have to pay £2 a sluice-head per week for the water, when the water is available. The following parties have claims on this deposit: Fryar and party, two men; Fleming

and another, two men; Cullen Brothers, two men; Young and party, four men; and Hudson and party of six men.

Cullen Brothers informed me that they obtained 9oz. of gold from a very small piece of ground. Almost in every one of the claims visited the shareholders showed me a prospect by washing some of the material from the face in a tin dish, and the results in general were very encouraging. There is no doubt, with a good supply of water, that this ground could be made to pay extremely well, but with only a small supply the quantity of material that can be removed is very limited. The elevating plant referred to in my last year's report is still being worked, but not with success to the shareholders. Indeed, this is not to be wondered at, as the plant is only suitable for prospecting, and not for working the ground. It is far too small to be of any great utility in working the ground. The yield from this field last year has been about 1,200oz., and there have been about seventy-five miners employed in claims.

Crown Terrace.

The Crown Terrace lies on the east side of the lower course of the Arrow River, and abuts against the southern end of the Crown Range at a height of from 500ft. to 800ft. above the level of the river. The flat shoulder thus formed extends down the Kawarau to the Kawarau Bridge. The material forming the Crown Terrace is either local, or has been brought down by the Arrow River and poured into an extension of Lake Wakatipu, of which the Crown Terrace was the shore-line prior to the advance of the glaciers that filled it to Kingston, Franktown, and Arthur's Point.

Gold is only being worked at the northern end of the Crown Terrace, where the auriferous material may the more reasonably be supposed to be brought down by the Arrow River. The yield is payable where plenty of water can be applied satisfactorily. Claims are being worked both above and below the line of Tobin's Road, and on the steep slope between the road-line and the Arrow River it is supposed that a rich terrace at a lower level has been covered up by a slip. Nothing, however, has been done to prove whether this be the truth or not, and further prospecting may lead to better ground being discovered.

There are a few men working on the face of the terrace fronting the Arrow River, near the side of the road that comes from the Crown Terrace down to the township near the entrance into the gorge of the Arrow River. This land was resumed from Mr. Baker, who held it on an agricultural lease. There has not, however, been many claims worked; they are principally on the face of the terrace. Some of the people in this locality state that the run of gold is now going into land held in fee-simple by Mr. Paterson, and wish to have the land resumed. It is questionable, however, if sufficient prospecting has been done to warrant the resumption of this land.

Arrow River and Terraces.

There are some very fair sluicing-claims on the side of the terraces facing the Arrow River and Bracken's Creek: now and then, between Arrowtown and Macetown. The Arrow Falls Tunnel Company, which belonged to a syndicate of Melbourne gentlemen known as Moody, Davis, and Company, was sold by the mortgagee, and purchased, along with the same syndicate's property on Burke's, Londonderry, and Pleasant Creek Terraces, alongside the Shotover River, for the sum of £3,000 by James Miller. At the time of my visit the gates at the upper end of the tunnel had been damaged by a heavy flood in the river, which occurred some time prior to my visit. The proprietors, James and David Miller, do not consider that the damage is of any consequence, as the surface material run off will compensate them for any repairs. There is, however, a good deal of work yet before surface material can be run off, and almost the whole of this has to be done before the proprietors can expect much gold. Whatever gold there is in the bed of the river, it is near the rock bottom. The slip, which now forms the falls in the river, has dammed it up, and the sand and gravel coming down by the stream simply lodged in this dam, so that there must be about a depth of 50ft. of worthless material to be run off before the original river-bed wash can be got at.

Mr. Miller has, however, a very good way of working, and if he is fortunate in not having his headworks damaged with floods, a few months ought to see the bed of the river laid bare, and if it proves to be as rich as other portions of the bed, these men will get well paid for their outlay. They have the advantage that there is no head-race required; all the material can be manipulated with the water in the river, and few men are required to carry on the work.

There is a very good prospect of this venture proving remunerative, as very rich auriferous wash-drift was found in the bed of the river in the early days, both above and below the falls, where the rock bottom could be reached, and several attempts were made to sink paddocks and shafts in the ground that is now being worked, but the influx of water always proved too great to contend with.

There is a large extent of auriferous gravel-wash on the terraces between this and Macetown, but some of it is at so high an elevation that water could not be brought on to work it. There are several small parties working on the face of these terraces which make fair wages. One party has gone to considerable expense in bringing in a race from the Arrow River, on the opposite side to Macetown, and taking the water across the river in a wrought-iron syphon. The pipes are very small, but even with a small supply of water this party is doing very well.

There are also gravel terraces along the side of Macetown Creek, near its junction with the Arrow River, which would pay for working if there was water to command them. In the early days very rich patches of gold were found in the bed and banks of Macetown Creek, and still a few miners are making a livelihood in this place. The gold found in this creek is merely from a concentration of the material by the water cutting down the bed and the gravel from the terraces being washed away.

Shotover.

Below Maori Point the Shotover is confined to a narrow gorge, the mountains on each side rising very abruptly without fringing terraces of any kind; but above Deep Creek, though the

river is still confined to a narrow and deeply excavated channel, there are narrow flats on both sides of the valley at from 150ft. to 500ft. above the level of the river. These, to a depth of from 20ft. to 200ft., are covered with river-shingle, deposited by the Shotover River, Stony and Skipper's Creeks, when these flowed at a higher level. There is some evidence favouring the assumption that the valley between Maori Point and Skipper's at one time formed a lake, which has been drained by the cutting of the gorge between Deep Creek and the junction of Moke Creek.

High level gravels lie on the point of the spur at Skipper's Point, and are met with on the left side of the valley of Skipper's Creek, midway on the road to Bullendale. A very considerable amount of sluicing has been done in the deep gravel terraces of Maori Point, especially on the Stony Creek side of the river, and at Skipper's Point.

There is still material to operate upon that, at the present rate, will last for many years.

On Stony Creek Terrace, Davis Brothers have been working for many years and getting good returns. The face they are now working is about 200ft. in height, and as they get back into the ground the fall for tail-races is getting very small. One of the brothers, it is said, has left the claim and accepted a situation as mine-manager, but probably he still retains his interest, and finds the present employment more congenial to his tastes. The inference is that the ground cannot be very rich, or else a man would not leave it to go elsewhere.

R. Johnston's Claim.—This claim is on Pleasant Creek Terrace, on the same old river-wash as Davis Brothers are working. Mr. Johnston always informs me that he is well satisfied with the returns, but takes very good care not to commit himself as to the quantity of gold he obtains. He has been working on the same terrace now for many years, and, judging from the time he has been working and the area of ground he has gone over, he will never live to see his claim worked out.

Miller Brothers' Claim.—This is a portion of the property which formerly belonged to Messrs. Moody and Davis's syndicate, of Melbourne. Mr. D. Miller, the former manager, along with his brother, is now working this ground, together with the Arrow Tunnel Claim, on their own behalf. At the time of my visit a large cut had been taken in on Londonderry Terrace, but the returns from the workings at that time had not come up to expectations. There is a splendid supply of water, and the workings are carried on in a very systematic manner, but the gold does not appear to be in the ground, at least, as far as they had worked. They expect, however, to find better ground ahead of where they are working. Anyone, to look at the ground and the character of the wash-drift near the bottom, would think that it ought to carry gold, it having apparently been the bed of the Shotover River at some previous period; but, from the information afforded me during my recent visit, it appears doubtful if these terraces contain the rich auriferous drift that many believe them to do. No doubt there are several runs of gold-bearing wash where the ground has been driven out, but the great depth of gravel now lying on the top of the ancient river-wash, containing very little gold in it, gives but a poor return for washing the whole of it away. It really means that it is only by having a large supply of water that such ground can be worked remuneratively.

Aspinal's Claim.—This is one of the best claims in the Shotover district, it being situated at the junction of the Shotover River and Skipper's Creek. The supply of water is very limited. From the information afforded me it seems that with about six sluice-heads of water working in the ground for about an hour 2oz. of gold can be obtained; but it is only in very wet seasons when a supply of six sluice-heads can be got for two or three hours a day. There is a small dam that stores two or three hours' water, with a catch-water race leading into it.

There are several small claims being worked on the terraces alongside the Shotover, above the junction of Skipper's, and whenever there is a moderate supply of water to be got, good returns are obtained. There appears to be very few, if any, miners come to this place from other fields. One sees the same old faces year after year, and some of the miners now working on the Upper Shotover have never left this portion of the district since it was first opened. Many of them complain that the ground is gradually getting poorer, but that they do not know of any other place where they can do better.

Preservation Inlet.

Gold has now been found in the alluvial drifts in a number of places—namely, Wilson River, Sealers' Creek, Coal Island, and Crayfish Island, and no doubt it will be found extending both ways, especially in the direction of the Waiau River. Several people have reported that there is gold in the drift in the creek-beds between Wilson's River and the Big River, but no one has so far done any real prospecting to know whether the ground would be payable for working or not. This is not to be wondered at, seeing the nature of the country through which men have to travel and carry their provisions. Indeed, this country will never be prospected to any extent until such time as the horse-track is constructed between Wilson's River and the Waiau, so as to have communication by land to the whole of this country. At the present time, the only means of communication is by sea. If the horse-track were completed, there is a considerable area of good land between the Waiau and Big Rivers that would be taken up for settlement.

Wilson's River.—The river claims are getting worked out; there are only three parties of three men each working claims in the river, and a few parties working on the terraces. About twenty men altogether working in alluvial ground, and, as far as can be ascertained, they are not making large wages.

Sealers' Creek.—There are six men working in the vicinity of Sealers' Creek No. 1 sluicing the terraces along the side of the creek, and they are said to be getting well paid for their labour. The alluvial drift is full of quartz, and some very rich specimens containing gold have been obtained amongst the wash-drift. The whole of the gold shows that it has come from a quartz lode and not travelled very far, as it is all of a filiform character, with a great deal of quartz adhering to it. The parties working in this locality feel certain that as they work up towards the head of the creek they will cut a quartz lode, and, if so, it is likely to be a rich one.

McNamara's Creek.—This is between Sealers' Creek and Wilson's River. There is a party of three men working here. They are at present engaged in cutting a head-race to bring in water at such a level as will work the terraces by hydraulic sluicing. There is very good sluicing ground in this locality. In the claim held by the party referred to prospects can be obtained from ½gr. to 1gr. of gold to the dish, from the surface to the bottom, and, according to the information given with regard to this place, the run of auriferous drift is likely to extend up the creek for a distance of two miles. It would seem that with a good supply of water on this ground men will make good wages in this locality.

Coal Island.—There are about twenty miners located on this island working in the different gullies, but, as far as can be ascertained, none of them are making large wages. There are several drift terraces here which have never been prospected, the workings being chiefly confined to the creek-beds. The supply of water available on the island is very limited, and cannot be taken to command any high ground to work it advantageously.

Crayfish Island.—There has been a recent discovery of gold on this island. In January last a rich auriferous deposit of drift was found by Mr. Bradshaw and party, and, up to the end of March last, it is said that this party, consisting of six men, had got about 150oz. gold. There are now four parties of miners working on the island who are all said to be making very good wages. From reliable information supplied me, the total quantity of gold obtained on this island from the middle of January to the end of March exceeded 300oz. Those who have claims here state that the prospects are very regular through the wash-drift, and that alluvial mining is likely to last and give payable returns for a considerable time to come. There are about twenty-nine miners now working on this island.

DREDGING.

Otago District.

This class of gold-mining is gaining ground every day; but, so far, the Welman or suction dredge has not been attended with great success. Nevertheless, it works very well where there is not a large quantity of stones or coarse gravel. The centre-bucket dredge is most used, and for river-work or wet ground in flats where there is little or no fall it is the most profitable machine that can be used for gold-mining. It has not been so successful in working the ocean-beaches, but this is in a great measure due to the character of the gold, which is of an extremely fine and scaly character and difficult to save. No better machine can be got for lifting the material, but the gold-saving appliances for this character of gold have not been all that could be desired. When the gold is moderately coarse—or, even if it is fine, so long as it is of a solid, compact nature—there is very little trouble in saving a moderate percentage of it—namely, what the miners would term "good weighing gold"; but when it is of an extremely thin, flaky character, as it is generally found on the ocean-beach, the gold-bearing sand has to be passed in a very thin film over wide sets of tables covered with cocoanut-matting or blankets specially made for these purposes. The miners working on the ocean-beaches, generally termed "beach-combers," have no difficulty in saving the gold; but the quantity they put over their tables is very small, and only the layers containing gold are washed, whereas a dredge lifts everything, and all the material has to pass through the sluice and tables.

When dredging was first commenced there was a great rush for ground in both river- and creek-beds, and almost every ocean-beach where gold was found was taken up as dredging-claims, and dredges could not be made fast enough to satisfy the demand; but we are now past this stage, and going on in a more systematic manner. There are now very few of the dredges but what are made paying concerns, and those which have been employed in dredging the Waipori Flat show that they are the best and most economical machines that can be used to work wet ground, when the depth does not exceed 30ft., but this seems to be about the limit to which they can work successfully. It is, however, a question of the length of the bucket-ladder. If this were sufficiently long, and the hull of the dredge,or it may be termed the pontoon, or barge, which carries the dredging machinery, were large enough, no doubt they could be made to dredge to a much greater depth. Even with the present dredges many find that the hulls or barges are now made too small. They require a good length and beam to keep them steady when working so that the washing appliances may have a better chance of saving the gold. Every dredge that is used in gold-mining cannot expect to become a payable venture, any more than every claim that is taken up by miners and worked in the ordinary way; if the gold is not in the ground they cannot under any circumstances be made to pay the expenses of working. More care is now exercised in selecting the ground, the time having gone by when men with a few pounds rushed in to procure shares. In most of the dredging companies the shares are held as purely a commercial venture, and the profits on the working are looked forward to as interest on the capital invested, although, unfortunately, some of these ventures return but very little interest.

There are now seventeen steam-dredges on the Clutha River, between Clyde and the Island Block, and two current-wheel dredges; seven of these are between Clyde and the Manuherikia Gorge, and twelve between Coal Creek and the Island Block. Two of the steam-dredges and one current-wheel dredge are not yet actually at work; they are being put together on the side of the river. Taking the number actually working, there are about one hundred men employed in dredging operations, and during last year about 8,086oz. of gold was obtained by the use of these machines, which would represent a value of about £32,000; in addition to the men actually employed in dredging operations, there is a large number of men employed in getting and carting coal. During last year about 9,400 tons of coal were consumed by these dredges.

Name of Party or Company.	Number of Dredges.	Gold obtained.	Dividends paid.
		Oz.	£
Golden River Company ...	1	814	1,175
Pringle and party ...	1	Not known	Good wages.
Bennet and party ...	1	"	"
Brazil and party	1	"	"
Golden Treasure Company	1	Dredge just completed	Nil.
Miller's Creek Company...	1	300	"
Ettrick Company... ...	1	545	"
Dewar and party... ...	1	200	Wages.
Edina Company	1	Only commenced working	Ground good.
Roxburgh Company ...	1	567	750
Dunedin Dredging Comp'y	2	1,602	2,610
Simmonds and party ...	1	Dredge just completed	...
Dunedin Company ...	1	Dredge in course of construction	...
Spence and party ...	1	About 20oz. per week	Very good wages.
Hyde and party	1	25oz. to 30oz. per week	"
Leyon and party	1	Not known	Said to be doing remarkably well.
Louis Gards	2	1,250	Private venture.

A good many of these dredges are owned by private parties of three and four men, who have been engaged in dredging operations on the Clutha River for a number of years. When their dredges were first built they were worked by current-wheels, but it was found that these dredges would only work where the current was strong; and therefore they could not be utilised for working in any of the bays where there was an eddy. Consequently, the most of them have now been altered into steam-dredges. It may be fairly said that, taking the capital invested in these dredges to average £3,500 each, then the cost would be about £66,500, and it will be seen from the foregoing statement that there are four of the dredges which have not yet done any work. The actual profit on the working of the remaining fifteen dredges may be set down at about £7,650, which is equal to 11½ per cent. on the whole of the capital invested in dredges on this portion of the Clutha River.

There are five dredges on the Shotover River, four of which belong to the Sew Hoy Company at the Big Beach and Arthur's Point, and one at the Sandhills. The Sew Hoy Company have been paying regular dividends. This company first put one dredge on to the Shotover River at the Big Beach, but it was too small to dredge down to the bed rock. The working of it, however, showed that this beach would pay for dredging with a proper plant. The company got three other dredges constructed, and these have been working during the past three years, while the first dredge has been laid up.

In addition to the dredges, the company during the last year erected a hydraulic elevator near the mouth of the gorge at Arthur's Point. Very rich deposits of auriferous drift were obtained here in the early days, and in order to work the bed of the river at this place a dam was constructed near the mouth of the gorge and the river turned out of its bed. The dam was washed away a number of years ago, but the ground underneath where the dam was constructed has never been worked. It is in this portion of the river-bed where a hydraulic elevator has been placed, but so far it has not been worked with success, owing, it is said, to the number of large boulders in the drift and the limited water-supply that can be got with sufficient head to work the elevator. It will be interesting to show the result of carrying on dredging operations by the Sew Hoy Company since it commenced working these dredges:—

Value of Gold produced.	Expenditure.				Total Expenditure.
	Wages.	Value of Coal consumed.	Cost of Repairs.	Dividends paid.	
	£ s. d.	£	£	£ s. d.	£ s. d.
March, 1889, to Nov., 1890 ..	4,687 8 10	1,578	803	415	1,350 0 0	4,146 0 0
Nov., 1890, to 31st Oct., 1891 ..	9,509 10 2	4,054	2,151	690	..	6,895 0 0
1st Nov., 1891, to 31st Oct., 1892	17,170 7 7	5,213	2,636	947	5,377 10 0	14,173 10 0
1st Nov., 1892, to 31st Oct., 1893	15,587 19 6	5,269	2,327	1,579	3,360 18 9	12,535 18 9
1st Nov., 1893, to 31st March, 1894	8,683 9 1	2,020	894	..	2,016 11 3	4,930 11 3
	55,638 15 2	18,134	8,811	3,631	12,105 0 0	42,681 0 0

It will be seen from this that the value of the gold produced has amounted to £55,638 15s. 2d., and the total expenditure in connection with the working of these dredges, £30,576, exclusive of dividends paid to the shareholders, which have amounted to £12,105. The last three dredges the company had constructed cost £11,000, and during the last year the hydraulic elevator, with races, &c., cost £1,900, there being about nine miles of water-races. It will also be seen that nothing is put down for repairs to the dredges for the last period ending the 31st March, and apparently nothing is charged to the management, office expenses, and directors' fees, &c.; but, taking the amount of money that has been paid in dividends, and the expenditure on dredges and elevators—

namely, £12,900—it proves that these dredges can be made profitable machines in connection with gold-mining.

The figures in connection with the results of working were kindly supplied me by Mr. T. Callender, the secretary of the company, and will no doubt interest those who are carrying on dredging operations.

Sandhills Company.—This company's dredging operations are in the Shotover River, about a mile and a half above the Sandhills. The nominal capital of the company is £12,500, and the actual capital paid up in cash is £7,142 4s. The nominal value of the shares is 10s., and 4,000 of these were given to shareholders, for which no cash was paid. This dredge is worked by an electric motor, the electricity being generated by Brush dynamos on the shore, which are driven by a Pelton water-wheel. The water-race which is brought in to drive the Pelton wheel is at a high elevation, and for a couple of months in winter the frost stops the supply of water; consequently, operations have to be suspended for a portion of the year. The ground is said to give fair returns where this dredge is working, but the working and office expenses seem to absorb the most of the profits, as only two small dividends have yet been paid to the shareholders, amounting in the aggregate to £849 18s. 10d.

Ophir.—A dredge was placed on the Manuherikia River below the bridge at Ophir by Messrs. Gallagher and Harrington, but it was constructed on the Welman principle, and proved a failure. The wash-drift in the bed of the river at this place was found to be too tightly cemented together to be disintegrated by suction. The ground has therefore not been tested; but the owners of this dredge are so confident that there is gold here to pay for working that they are going to place a bucket-dredge on the ground.

Waipori.—There are two bucket-dredges at work at Waipori, but these have lately had to suspend operations, the proprietors having been served with an injunction from the Supreme Court at the instigation of some of the settlers in the vicinity of Berwick to stop working, on account of the large quantity of silt that was coming down the Waipori River, which was said to be due to dredging operations; but, in all probability, the sluicing operations had as much to do with sending silt into the river as the dredges. In the early days the gold-workings had very little effect in making the water of the river muddy; but, the most of the shallow and rich ground being worked, the poorer ground requires to be operated on by a different method to make it remunerative. The days of paddocking have gone by, when only the wash-drift on the bottom was washed in a small sluice-box at intervals. Now, the ground has to be continuously worked with a good stream of water, and sent away in a wholesale manner, before the miners can earn wages. The accumulation of silt in the bed of the river has therefore been far more of late years than formerly.

The Waipori Gold-dredging Company has two dredges, but during the past year only one of them was at work—namely, the largest dredge—and at the time of my visit the operations were being carried on successfully. The dredge was working the banks at the side of the river, and getting a fair quantity of gold. The dredge is capable of lifting about 75 cubic yards of material per hour. This company has found that to work ground of this description it requires large dredges. The hulls or barges on which the dredging machinery is placed, along with the washing and gold-saving appliances, require to be much larger than they generally are made, in order to give room for ample gold-saving appliances to be placed, and also to give them sufficient stability when carrying on dredging operations.

The Jutland Flat Company has a dredge on the flat above the township, which has been working successfully for the last three years. Indeed, this may be said to be the best dredge yet constructed in the colony, and has been getting good returns ever since it has been at work; but, unfortunately, the operations have had to be suspended, owing to the injunction from the Supreme Court. It is to be hoped that the difficulty between the miners and the farmers in this locality will soon be settled, so as to allow dredging operations to be carried on. The ground in this flat can never be remuneratively worked by any other system, and there is a large area of land in the Waipori district which is not suitable for any other purpose but mining, except for the pasturage of a few sheep; and, now that dredging as applied to mining has been perfected to such an extent as to make it a profitable venture, and give employment to a number of men, every encouragement should be given to those who will embark their capital in such an undertaking, and so develop the gold-mining industry.

There are now a large number of dredges working in the Otago district on the goldfields, some of which have not been successful; but this is to be expected in many ventures of every description. But if sufficient care be taken in prospecting the ground by bore-holes previously to placing dredges on the ground, the most of the ventures could be brought to a successful issue. Some ground may be so full of large boulders that dredging would not be a suitable method of working it, even were there sufficient gold to pay for working. Neither can dredging operations be carried on with payable results if the wash-drift be hard-cemented together. In such ground the buckets only slide up against the wash without being able to disintegrate it. On the other hand, on some of the ocean-beaches the gold is of such an extremely fine, scaly character that the gold-saving appliances are not suitable for recovering it. Different methods have to be adopted for saving the gold, according to the character of the precious metal in the material to be treated.

West Coast.

Of the dredges on the West Coast, the most of them have proved failures. A number have been placed on the ocean-beaches, which contain sufficient gold, if it could be recovered; but, until very large tables are used, covered with cocoanut-matting or blanketing, on the same principle as adopted by the miners working on the beaches, there is little hope of success attending the dredging operations. This seems to be the greatest difficulty to contend with, as the hulls or barges which carry the dredging machinery are not sufficiently large to admit of a large area of tables being

used. These tables are not required to be long, but to be of a great width, so that, after the fine gravel and shingle is separated from the sand, the residue is distributed in a very thin film over a wide extent of tables. No doubt this difficulty will be got over, and dredging yet carried on successfully on the ocean-beaches; but a great length of time elapses, in many instances, before miners, and those interested in such operations, will depart from the beaten grooves. The dredges have been successful in making mining ventures remunerative on the rivers and flats in Otago by merely using long sluices and a very limited extent of tables; but the gold is of a totally different character from that found on the ocean-beaches on the West Coast, which requires a different method to be adopted for saving it.

On the Matakitaki River there has been a dredge at work for the last two years, and, from the information supplied me when in this district, the gold returns have proved that the bed of the river can be worked remuneratively. The operations were suspended at the time of my visit on account of the upper part of the claim where the dredge was first placed being worked out, and the manager was waiting for a fresh in the river to get the dredge floated down to the lower end of the claim. There is a great number of large stones in the bed of this river, and when the dredge was first placed on it, after working for some time, it was found that the ladder and gearing was not sufficiently strong to work the ground. This was afterwards strengthened, and since then payable returns have been obtained.

The Alexandra Company have a dredge on the Buller River, near Fern Flat, a little below the junction with the Matakitaki River, where there is very rich wash-drift in the bed of the river; but the hull of this dredge is by far too small, and the result is that it has been twice submerged in the river, and considerable expense gone to in recovering it, so that the most of the profits in the operations have gone in expenses in alterations and repairs to the machinery and appliances. If a suitable dredge had been placed here in the first instance the shareholders would have been getting good profits.

Another dredge is working on the Buller River, near the junction of the Dee, about a mile and a half from the junction of the Inangahua River with the Buller, and is said to be doing fairly well. It may be said that it is only a question of a little time when other ventures of this description will be started to work the auriferous drifts in the beds of the rivers and streams, which are known to contain a fair amount of gold.

COAL-MINING.

NORTHERN COALFIELDS.

There are large coal areas in the North Island, but the class of coal that is found is not equal to bituminous coal from the west coast of the Middle Island. There are small areas of lignite coal reaching from the mouth of the Tiaha River, following around the head-waters of Rutakaka River and around to the east side of the Whangaroa Harbour, but the coal is of a very poor quality. At Kawakawa there is a superior class of coal, being semi-bituminous and of good quality for marine purposes. The coalfield is, however, greatly broken, and the seam of coal is in places only a few inches in thickness, while in other places it is 8ft. thick. The Kawakawa Company, which has been working the coal here for the last twenty years, has abandoned the mine, and the company is now in liquidation. There is still, however, a considerable quantity of coal left in the ground, which has recently been worked by a co-operative company; but the output from this field in the future will be comparatively small.

Between Kawakawa and Hukerenui there are apparently some coal-bearing areas—for instance, at Waiomio and to the eastward of the main road, between Towai and Hukerenui; but as there are no outcrops on the surface the field can only be prospected by boring.

At Hikurangi, according to the latest survey of Mr. McKay, the Mining Geologist, the coal extends over an area of at least twenty square miles, of which nine square miles can certainly be worked; but the other portion is covered by an immense swamp, where it is questionable if the cover is sufficient to allow the coal to be taken out. There will certainly have to be a fair allowance made for faults, breaks, and rolls; but, after deducting for these, there is a comparatively large field, where a fair class of coal can be obtained suitable for ocean-going steamers, but nevertheless considerably inferior to bituminous coal. Mr. McKay states: "To the eastward, the coal-measures of the Hikurangi field rest upon old slates and sandstones, the lower beds and coal-seams successively appearing at the surface in this direction. To the north and north-west, the higher beds of the coal-bearing formation, the flint and fire-stone division of the Cretaceo-tertiary series being in this direction overlaid by volcanic rocks, or obscured by the turbary deposits of the Big Swamp or the alluviums deposited by the Whakapara River. To the westward, the practical limit of the field is the Big Swamp. How far coal may be mined under this is a question there is at present no means of answering. Towards the north-west, apart from the obscuring rocks of volcanic origin or recent date, the formation is terminated by resting on or abutting against the older rocks of the Puhipuhi table-land, and the ridge of the same rocks that extends west through the settlement of Hukerenui. This field is separated from Kamo coalfield by a range of slates and sandstones to the east, and to the west by volcanic rocks of a date younger than the coal formation, the age of which is the same on both fields."

In the Kamo coalfield, although of the same age as the Hikurangi and Kawakawa, the coal is inferior to coal obtained at either of the places mentioned. The Kamo Company, who expended a large sum of money in carrying on coal-mining operations here for years, had to suspend operations and close the mine during the past year. Before abandoning the mine, boring operations were carried on by the company on the adjoining property, and coal was found there in one of the bores, but in some of the other bores the coal was found wanting, apparently caused by a "wash-out."

At Ngunguru there is a small area containing very fair coal. It may be termed the best class of coal in the North Island. A private company has opened a mine there on Native land where there is a considerable thickness of good coal; but the harbour is so shallow that only light-draught vessels can come in. Therefore, the supply from this field will always be limited to the quantity that can be taken away. The great outcry of mine-proprietors in the North Island, who are depending on Auckland as a market where local coal can be used by the consumers, is that large quantities are brought from New South Wales, a great deal of which is taken as back-loading at a reduced rate. It therefore can be sold in the Auckland market at a lower rate than the local coal can be produced. The freight on small cargoes is considerably higher per ton than if it could be carried by vessels of 2,000 or 3,000 tons burden, and this militates against the working of mines where only small vessels can be used to carry the coal to markets.

In the Waikato field there is a considerable area of coal-bearing land, but a great portion of it is covered by immersed swamps, and the coal, although of a great thickness, is of inferior quality to that found at Ngunguru, Hikurangi, and Kawakawa. It is coal similar in quality to that of Shag Point and Kaitangata, and is only fit for consumption in the district in which it is raised, Auckland being the principal market. There are at the present three mines being worked—viz., the Waikato, Taupiri Extended, and the Taupiri Reserve. Formerly, there were two other mines being worked—viz., the Miranda and Ralph's; but the former has been abandoned, and the arrangement was come to with the Taupiri Extended and Taupiri Reserve Companies to lease Ralph's Mine, or at least induce the owner to suspend operations. The total quantity of coal produced from the Waikato mines last year was 57,251 tons.

Coming further south there is a large coal-bearing area extending from Kawhia Harbour across the Mokau River, but the only place where any coal-mining is carried on is at the Mokau River, about twenty miles up from its mouth, and then only a small quantity of coal is being got from one mine on the north side of the river, the output last year being only 781 tons. The coal is of a fair class for household purposes, but it contains a rather large percentage of sulphur. A mine was opened out on the south side of the river by a co-operative company on Mr. Joshua Jones's property, but work here has been suspended for nearly two years. The great difficulty here is getting away the coal to market. Only about from fifty to a hundred tons can be carried by the steamers that are used to take the coal away.

There is no mine yet opened in the North Island that can supply a really first-class coal to ocean-going vessels; neither has any coal been yet found of a first-class character. The demand for local consumption will always regulate the output from the mines, unless the Ngunguru or Hikurangi coal can be taken to where vessels of a large tonnage can come and take it in; and this would only apply to coaling-steamers in the coastal and intercolonial trade if it could be delivered at a port at such a price as to compete successfully with the better class of coal from the west coast of the Middle Island, and from New South Wales. Taking the whole of the output of coal from the North Island last year, it amounted to 92,718 tons, and there were 255 men employed in connection with the mines.

SOUTHERN COALFIELDS.

Westport District.

Westport Coal Company.—This company is a re-formation of the Westport Colliery Company, who had a capital of £100,000 in ten thousand shares of £10 each, but this was insufficient capital to carry on its operations. The present company was formed in September, 1881, with a capital of £400,000 in eighty thousand shares of £5 each. The price paid for the property was £84,000, of which £60,000 was paid by the issue of twenty-four thousand shares with £2 10s. paid up, and £24,000 in cash. The company's land is held under two leases from the Crown for a term of ninety-nine years; these comprise 5,430 acres. One of these leases is at Coalbrookdale, situate between the head of the Wareatea Creek and the Waimangaroa River. This lease contains an area of 2,480 acres. The seam of coal varies from 6ft. to 20ft. in thickness, and lies at an elevation of about 1,800ft. above sea-level.

The coal is brought from the workings to the bins and screens on the top of the hill at Denniston where the hauling machinery is erected. The main hauling-line is two miles through a tunnel from the Denniston side to the Coalbrookdale side of the range. The endless rope system is used for bringing the mine-tubs of coal from the workings to the staiths. At the end of the main hauling-line there are two subsidiary lines which connect the workings with the main line. The Coalbrookdale branch line is about one mile in length. The other branch line crosses the Waimangaroa, and opens up the field to the south-east. On both these branch lines some of the grades are very steep. The worst grade on the main hauling-line is 1 in 10, but on the branch lines the ruling grade on the one crossing the Waimangaroa is 1 in 5, and the Coalbrookdale line is 1 in 14. The main line is worked by a steel-wire rope 3½in. in circumference coiled in four turns round a surging-drum 6ft. 8in. in diameter. The annual output of coal since 1883 has been as follows:—

	Tons.		Tons.
1883	34,997	1890	160,240
1884	74,319	1891	192,604
1885	47,748	1892	198,466
1886	73,923	1893	223,500
1887	115,940		
1888	130,218	Total ...	1,415,879
1889	163,914		

The capital expended on the Coalbrookdale Mine has been about £150,000, and since 1887 the company has paid four dividends—namely, in 1887, a dividend of 2½ per cent. was paid; in 1888, a dividend of 5 per cent.; in 1889, a dividend of 6 per cent.; in 1890, a dividend of 7½ per cent.

During the past year an expenditure of about £30,000 has been made in opening up their other mine at Granity Creek, which contains an area of 2,950 acres, and this expenditure has absorbed the profits of workings of the Coalbrookdale Mine.

From Denniston to the bottom of the hill at the termination of the railway there is an incline in two lengths; the upper incline is 33 chains in length, having a total fall of 830ft., having a maximum grade of 1 in 1·3, and the lower incline is 50 chains in length, having a ruling grade of 1 in 2·2. The inclines are worked by direct rope-haulage, the descending weight being utilised to haul up the empty wagons. These wagons when full of coal are about 11 tons in weight, a steel-wire rope 4in. in circumference being used in lowering them. Special brakes are used for lowering this weight. The brake used resembles a direct-acting winding-engine, but the action is exactly the converse. Water is used to check the action of the pistons instead of steam. The water is drawn off at each stroke and its place is supplied with cold water, as the heavy strain would otherwise raise its temperature to boiling-point. A strap brake was formerly used on the upper incline, but it wore away at such a rate as to not only cause considerable expense, but also great delay.

The incline is laid with flat-bottomed rails, 40lb. to the yard. At the top there are three lines of rails, and at the place where the wagons pass each other there is a double line, and below this passing-place there is only a single line.

The Granity Creek lease is about ten miles to the northward of the Coalbrookdale Mine. The company estimate that there is at least thirty million tons of coal in this lease. The coal-workings will be about 1,500ft. above the flat, and the coal will be brought down in the mine-tubs by an incline 51 chains in length; in this incline there are two tunnels, 10 chains and 12 chains respectively; these tunnels are each 10ft. wide and 7ft. high, and between the tunnels there is a skew bridge of 18ft. span, of four rolled-iron girders resting upon stone abutments. At the mouth of the second tunnel from the bottom, the hillside, which is very steep at this place, began to show signs of movement, which necessitated a very strong abutment being built up against the face of the steep rocks, the wall being 30ft. high, which cost about £2,000. At the top of the incline there is to be a hydraulic brake and two surging-drums, one behind the other; these have been ordered from England, and are to cost £1,800. The haulage-rope for the incline is 4¾in. in circumference, made of plough-steel—Lainglay Cradock rope. Coal-bins and screens, capable of storing 4,000 tons, will be constructed at the bottom of the incline, and the place laid off so that the storage of the bins can be increased to 10,000 tons.

On the flat at the bottom of the incline the sidings will be about 40 chains in length, and there will be seven lines of rails underneath the bins. This necessitates a filling-in of about 16,000 cubic yards of material. A large bridge is constructed across Granity Creek, having five lines of rails. Two workshops have been erected—namely, a blacksmith's and carpenter's, and also a large store for the storage of goods and material. In the blacksmith's and fitting-shop there is a steam-hammer, punching- and shearing-machines, a radial drilling-machine, and a screw-cutting Tangye lathe with 10-in. centres, with gap; also a screwing-machine, with steam-engine, and fan for blowing the blacksmith's fires. There are 400 tons of rails on hand, and 1,000 sleepers ready for laying down, and material for 300 mine-tubs, the tubs being made on the premises.

At the mine on the top of the hill there are 60 chains of drives open, and about 7,000 tons of coal have been tipped into the creek, and partly washed away. Two blocks, each 5½ chains square, have been holed round ready to start 50 faces when the works to take down the coal to the railway are completed. The workings and the top of the incline will be connected with a light railway, and two engines will be used for haulage. Provisions are being made for an output of about 500 tons a day when workings are commenced, and further provisions will be made for a prospective output of 200 tons per hour. The company estimates that it will yet cost about £20,000 to complete the works ready to send down coal.

During the time the Westport Coal Company have been carrying on operations it has paid away £1,147,014, namely:—

	£
Wages	499,345
Royalty, railway haulage, rates and taxes	236,217
Freights to local carriers	346,892
Stores and material	64,560
	£1,147,014

At the present time the company pays away about £70,000 per annum, and this will be considerably increased when Granity Creek Mine is opened.

The coal from this company's mines compares very favourably with the North of England and Welsh coal, as will be seen by the following tests which were made at Woolwich Dockyard:—

Place where Coal was got.	Pounds Water evaporated by 1lb. Coal at Constant Temperature. Feed-water 100°.	Percentage of		
		Clinkers.	Ash.	Ash and Clinkers.
Average North of England coal ...	8·25	1	4	5
" Welsh " ...	9·11	1·94	4·22	6·16
" New South Wales " ...	8·30	2·11	7·15	9.26
" Coalbrookdale " ...	9·83	0·91	3·30	4·21

Cardiff Coal Company.—This company purchased the coal-lease which was held by Mr. A. D. Bayfield and others, and during the last year it has spent about £10,000 in opening out the mine and laying down tramways, sidings, and erecting bins for the storage of coal. The whole of the works has been laid out by Mr. Broome, mining engineer, and the mine itself is under the management of Mr. Elliott.

Sidings.—The length of the main line of railway which joins the Mokihinui Company's railway, is 26 chains, and the total length of sidings for holding empty and full railway-wagons is 45 chains. There are three lines of rails under the coal-bins, where railway-wagons can be filled, and the grade on the railway-line from the bins to the Mokihinui is 1 in 100.

Bins.—Substantial coal-bins have been constructed to hold 800 tons of coal. These bins are so arranged that two doors or gates can be opened to allow the coal to fall into each wagon, so that it can be filled in about three minutes. The bins are made with flat bottoms; but there are different compartments into which the coal can be tipped, so as to separate the various classes of coal. There are nine tumblers erected over the bins where mine-tubs are emptied. The bins are erected on the flat ground, and connected by a viaduct to the lower end of the tramway-line or incline on the side of the terrace, the distance being 236ft. The tubs coming down the incline are detached from the rope, and come on towards the coal-bins on a grade of 1 in 64. The empty tubs are sent down another line of rails, which has a steep incline for a few feet, giving them sufficient velocity to run on the level for a certain distance, where they are again attached to the endless rope by merely allowing the rope to fall into double V, which projects above the top of the tubs at each end.

Incline.—The incline-tramway is 46 chains in length from the end of the viaduct to the point where the coal is first cut, the total rise in this distance being 142ft., which gives an average grade of about 1 in 21·4. The steepest portion is at the lower end. For the first 4 chains the grade is 1 in 5·5, and for the next 5 chains it is gradually reduced to 1 in 36·7; and from this point to the mouth of the tunnel, which commences at 40 chains, the grade is reduced to 1 in 44. There is a short tunnel 4 chains in length near the bottom of the incline going through the brow of the terrace to get on to the narrow belt of comparatively flat land on top. The tunnels are made 9ft. wide by 7ft. high.

Otago District.

Kaitangata Company.—This company's coal-mine has been greatly developed during the last five years, and all the modern appliances used to produce the coal at the cheapest rate. The mine was well and carefully laid out when opening it out, and the workings carried on since then in a systematic manner. Great care is essentially necessary in working this mine, as the coal is very liable to spontaneous combustion. All the slack has to be cleaned out of the bords, and pillars showing any signs of crushing have to be watched to see that a fire does not take place. Spontaneous combustion takes place everywhere that atmospheric air can penetrate through or mix with the coal. The mine is, however, divided into districts, which can be cut off from one another in the event of a fire taking place.

There has been a large yearly output from this mine for a number of years, nothwithstanding the coal being of a quality that its consumption is confined to the district in which it is raised. It is not suitable for marine purposes, neither will it stand the weather the same as bituminous coal. There are several seams of coal in the mine overlying one another, but what is termed the main seam has a varying thickness of from 8ft. to over 30ft. The seams are, however, greatly broken up by faults. At what is termed No. 1 fault the displacement shows an up-throw of about 190ft.; and by following on the seams for about 13 chains into the hill No. 2 fault is met with, which causes a down-throw of about 280ft.; and in about 5½ chains further on the seams beyond the No. 2 fault another dislocation is met with, which is termed No. 3 fault. Going in the opposite direction from No. 1 fault towards the shaft, after following the main seam for a distance of about 7 chains, its inclinations gradually get steeper, until getting near the shaft the dip is steeper than 1 in 1; but taking the inclination of the seam between Nos. 1 and 2 faults it is about 1 in 4. Coming towards the shaft two more faults are met with, which cause very slight dislocations. In sinking the shaft and cutting towards the main seam six different beds of coal have been gone through, and the material underlying the main seam indicates that there is a great likelihood of other coal seams, or at least one more seam, under the present workings. The more cover there is on the coal the harder it is likely to be; but there is very little probability of getting bituminous coal under the present beds, although it is likely that a better class of similar coal to what is now being taken out will be got.

The principal output at the present time is from the inclined adit, which is 1,100ft. long, at the bottom of which a main heading is taken in on the level for 1,000ft., when it cuts the main seam beyond No. 2 fault. A dip incline was at the time of my visit being constructed towards the main heading leading from the bottom of the shaft, and only wanted a few yards of being connected with the shaft-workings. When this connection is made a good current of air will pass through, which will give efficient ventilation for some time in the deep working from the shaft.

The cover above the coal is a breccia-conglomerate, of a tough and tolerably hard character, and where it is solid, without joints and shakes, makes a very good roof. The same character of conglomerate is between every coal-bed that has been passed through, but the nodules or pebbles among the material seem to be coarser on the top covering than they are below. So long as this conglomerate occurs under the seams there is always the probability of getting another workable seam of coal lower down.

The machinery and appliances for preparing the coal for market are more complete at this mine than at any other in the colony. The tipplers and automatic screening-machine are all that can be desired. The screening-machine has the upper bars 8ft. long, half an inch in thickness, and 3in. in depth, with 1in. opening between each bar; the screen has a travel of 7in., and makes ninety strokes per minute. The coal that does not pass through the upper grating falls on a travelling horizontal belt, which conveys the coal from screen for a distance of about 30ft., and discharges it into the

railway-trucks by means of an inclined chute. The coal passing through the upper bars goes on to another screen, having a mesh of about ¾in. All the coal that will not go through the ¾in. mesh is termed "nuts"; and the coal that passes through the second screen falls on a third one, with ¼in. meshes; and what does not pass through the ¼in. mesh falls into another truck, and is termed "peas" which is sold at a cheaper rate than nuts; and after this the residue is all a waste product. But were there proper compressing coal-brick machinery the whole of the coal refuse could be made a marketable product.

If the same care were exercised in preparing the coal for market at the Brunner Mine, we should never have heard of so much slack coal being emptied into the Grey River. The travelling table or belt, which conveys the coal from the screens to the railway-wagons, is made of iron plates 1ft. wide and ⅛in. in thickness, all hinged together. The pulleys or drums at each end of the belt are hectagonal. The belt is the same width as the screens, namely 5ft., and, as it travels at a comparatively slow rate, there is plenty of time for a man or a boy to pick out any pieces of stone or shale from among the coal before it is conveyed the length of the chute which fills the railway-trucks.

This company has also first-class air-compressing engines, which came out from England some years ago for the Wallsend Company at Brunner. The engines, made by Walker Brothers, of Wigan, have double cylinders 26in. in diameter, and 4ft. stroke. The winding-engines have two cylinders, each 20in. in diameter, with a piston-stroke of 4ft. 6in. The winding-drum is 12ft. in diameter, and the rope used for winding is of Lang's patent plough steel, 3½in. in circumference. All the plant and machinery used are in good condition, and some of it is large enough for a mine where the output is double that at this one. The surface-works are lighted up at night with one of Thomson's dynamos made by the New Zealand Engineering Company, Dunedin. The dynamo is driven by a vertical steam-engine with 9in. cylinder and 1ft. stroke, the dynamo making 1,170 revolutions per minute when its current and force registers 45 amperes and 110 volts respectively. There is also another steam-engine for winding from the incline erected in a separate building. This engine has double cylinders 9in. in diameter. The winding-drum is 12ft. in diameter, but this is worked by geared wheels from the engines. The whole of the steam is supplied by three Cornish boilers made of steel, 6ft. in diameter and 30ft. long, having four Galloway tubes in each, and worked up to a pressure of 70lb. per square inch.

Castle Hill Company.—This company's leasehold adjoins the Kaitangata Company's holding. The company has for the last three years being expending a large sum of money in trying to open out a mine. They sunk a shaft to a depth of about 430ft., when a band of fine sand with water was met with, which made sinking very expensive. The shaft is either 10ft. or 12ft. in diameter, and lined with bricks all the way down; but there was no sign of any coal met with in sinking. After getting the shaft down this depth it was deemed more advantageous for the working of the mine and opening it out, to drive a dip heading from the face of the hill. This heading was completed a few days prior to my visit, and a seam of workable coal cut. The heading is carried down for a distance of 2,100ft. on an inclination of 1 in 4½; the vertical depth of the coal below the level of the top of the shaft when it was cut, would therefore be about 466ft. The coal is hard and compact, and some of it comes out in large blocks, but what was taken out of the mine prior to my visit had not that bright appearance of the coal from the Kaitangata Company's mine; but there had not been sufficient work then done to judge of the coal, which appears to be discoloured by oxide of iron in the water.

The workings are kept dry by a three-throw pump, capable of lifting about 14,000 gallons of water per hour. Preparations were being made at the time of my visit for getting the hoppers constructed and railway-sidings laid down, which will require to be completed before any coal can be taken to the surface. There is a good winding-engine erected, having 20in. cylinders and 5ft. stroke, made by A. Barclay and Sons, of Kilmarnock; and there is a dynamo of similar make and size as that of the Kaitangata Company for lighting the surface-works. The whole of the work yet undertaken is being done in a systematic and substantial manner, and shows that provisions are made for a large output. When once this mine is opened up, and in a position to send a large quantity into the market, it will then become a question of supply and demand; two companies will then be competing with each other for the trade which is purely confined to a district which does not extend beyond a radius of 100 miles, as this coal does not stand an exposure to the atmosphere for any great length of time without breaking up; neither could a large quantity of it be stacked for a long time without spontaneous combustion taking place.

There is little doubt but what this company will have to contend with faults the same as the Kaitangata Company, and it appeared from the colour of the coal that was on the surface, that the heading was not a great distance from one; but, be that as it may, the shaft has been sunk in a position that a considerable depth would have to be sunk before it will cut the coal-beds, as they dip at a very high inclination going in that direction.

The total output of coal from the whole of the coal-mines in the Middle Island last year was 691,548 tons, and there were 1,888 men employed in connection with the mines.

MINING MACHINERY.

THE MUDIE ORE-CRUSHER AND GOLD-SAVER.

A sketch of this machine was shown in my annual report two years ago, but, since then, the patentees have made considerable improvements, and made it a very complete ore-crusher. It cannot be said that a sufficient number of them has yet been tested to estimate the wear-and-tear as compared with a stamp-battery; but a gentleman interested in this patent waited on me about

three months ago and gave me all particulars about the machine, and he is prepared to verify them by giving a written guarantee with each machine that it will fulfil the conditions which are claimed for it, namely:—

That a machine having a crushing-capacity of 50 tons of ore through a 60-mesh screen, or a punched grating having 200 holes to the square, will only require three-horse power to work it, and the wear-and-tear of the machine is not above 50 per cent. of that of a stamp-mill.

The machine consists of three semi-cylindrical chambers, each about 4ft. in diameter, and 2ft. 6in. long, bolted together in line. Each chamber is fitted with a rocker. When the machine is set up it will be found that each chamber "sits" about 2in. below the preceding one. This allows fall for the milled material from one chamber to the other.

The crushing and grinding is effected by placing in each chamber a cast-iron roller with chilled face. The rollers work freely on a false bottom from side to side in line with and right over each rocker. The feed is at the top or highest end. The material is ordinarily reduced in the first chamber to pass through a grating with 30 holes, in the second to 80 holes, and third to 200 to 250 holes to the inch. If it is required to reduce it finer the supply of water can be reduced, which will give the required result.

The motion is that of a cradle on its rockers; this causes the crusher to roll from side to side with a steady crushing movement—crushing and amalgamating at the same time. The mercury in the ripples has the same backward and forward motion, which keeps it bright and clean, and gives every facility for a perfect amalgamation.

The gold-saving commences after the material passes the first crusher in a compartment which contains copper-lined mercury ripples, depressed about 1in. below the bottom of the chamber and running across the machine. This is repeated after each chamber, so that whatever gold is liberated in the chamber is caught and amalgamated before the material passes under the next crusher. By this process the reduction of the material is graded in each chamber, and the gold caught as soon as liberated from the quartz.

The motive-power required to run a plant capable of treating 50 tons of quartz per week, working twenty-four hours per day, is not more than three-horse, and to run a hundred-ton plant, six-horse power.

There is a great objection to the use of any new machine for ore-crushing until it has been thoroughly tested. There has been such a number invented, which failed to fulfil the conditions claimed for them, and the result is that the majority of mill-men pin their faith on the old stamp-mill, which, at the best, is only a crude appliance for pulverising ores. There are great difficulties in the way of designing a quartz-pulveriser. There are numerous conflicting conditions to be fulfilled, and it must be a machine that will work efficiently under all circumstances, be simple in its construction, substantially made, easily repaired, and the cost of wear-and-tear must be smaller than in other machines; and it must also be a machine which will crush the ore into a granular condition, so as to have it as free from slimes as possible.

Each machine has three rolls, which are about 28cwt. each. The rolls are 2ft. 6in. in diameter, and about 17in. across the face. Each of these rolls works back and forward in a cast-iron semicircular trough, having a lining of steel or hæmatite iron in the inside which comes up to within about 9in. from the top of the trough. This trough works on a rocker, and the travel of each roll is 3ft. each stroke, and, as the machine makes forty-six strokes per minute, the travel of each roll is 138ft. per minute, thereby having about 180 square feet of crushing-surface per minute; or, the three rolls which are in each machine have 540ft. of crushing-surface per minute. The ore is fed in at one end, and is crushed to a certain fineness in the first one, when it passes into the second, and again into the third, the fine material passing away from the last one. There are corrugated silver and copper plates which the ore passes over from each roll. Judging from the plans and description of the machine, it will yet find favour amongst mill-men. Every part of it is strong and simple, there being no complicated parts in connection with it. The price is £250, including all connections and bolts for the foundation logs. The patentees state that a machine having 100 tons a week crushing-capacity only occupies a floor-space of 10ft. square, and that the cost of bed-logs and fitting up is only about £5. This appears a very small sum, and it is very questionable if anything like that amount would fit one up. Good foundations are the principal thing to look at in fitting up crushing machinery, and when these are not firm and immovable the vibration of any machine of this description will soon cause a shake which destroys the force intended to be expended in pulverising, and very soon cause a breakdown in some parts of the machinery. The machine is, however, well worthy of a trial. The principle is not entirely new; some of the dollies used for crushing by hand in the early days of quartz-mining in Victoria were constructed on a somewhat similar principle.

THE MERCUR MINING COMPANY'S CYANIDE MILL.

The Mercur Mining Company's cyanide mill is not a model plant, but the interest excited by the successful operation of the cyanide process there makes reference to it of more than passing value. The mill was not built for a cyanide plant, nor was the mine originally thought to be gold-bearing. When the Mercur vein was discovered it was believed, as its name would imply, to be a deposit carrying quicksilver. Indeed, it does; but not in sufficient quantity to make the extraction of that metal profitable. Finally, the ore was found to contain gold in paying quantities, although finely disseminated in the gangue. Then a pan-amalgamation mill was built, as the ore could not be worked by the ordinary process of plate amalgamation. It turned out later that the pan-mill could do very little better, saving not over 40 per cent., it is said, the gold being very fine, while some of it existed as a mere coating on magnetic oxide of iron. Then, too, the nature of the gangue, which contained considerable silt, placed difficulties in the way of successful work. After this failure the plant was closed, and the owners began to look around for another process.

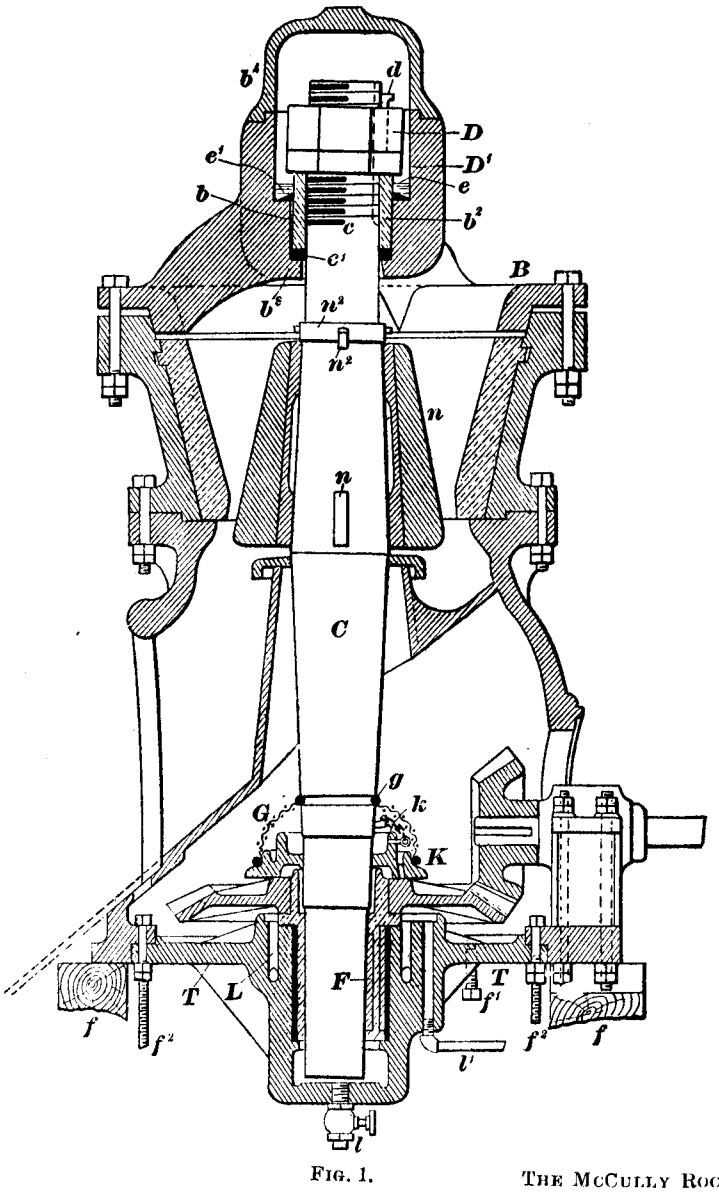


FIG. 1.

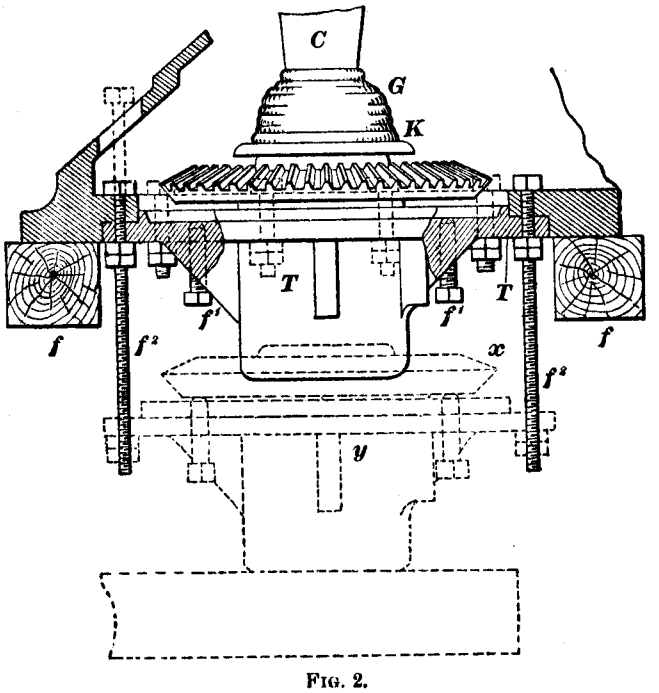


FIG. 2.

THE MCCULLY ROCK AND ORE CRUSHER.

After listening to the claims of various inventors a quantity of ore was sent to Danver for experiments with the cyanide process. Here the results were so good that the Mercur people were encouraged to alter their plant to a cyanide mill. That the mill as it stood at the time was not so convenient in arrangement as it might have been was due to its construction for another process, and really the work that has been done there is highly creditable from a metallurgical and from an economical standpoint when the numerous disadvantages are considered.

In the first place, the crushing is coarser than it should be. The rolls are not adapted for evenness of product, being the variety known as "Wall's corrugated." There are two sets of these to treat the ore which has passed a Dodge breaker, the primary ones being set to ½in. and the final to ¼in. Over 20 per cent. of the final product which is sent to the leaching-tanks refuses to pass a ¼in. mesh, while the nature of the ore prohibited fine crushing; such a coarse reduction was not advisable. Sizing-trommels would have prevented the formation of an excessive quantity of slimes, and would have furnished an even product which would have been leached to a much higher percentage than was then possible. The really unprecedented results which were obtained at the Mercur mill from this coarse ore gave rise to an opinion—erroneous, it is needless to say—that fine crushing was not necessary for the cyanide process; that the solution had the happy faculty of penetrating the gangue and carrying off the gold in its outward passage. Several mills were built under this mistaken idea which have not been so successful as they otherwise might. It is hoped that millmen are now thoroughly disabused of this opinion.

After the ore has passed the rolls it is carried over the vats in cars and is then discharged. In a properly constructed mill—one built to be worked with the utmost economy—this delivery to the vats would be automatic. Conveyors would take the ore after passing the screens and discharge it into hoppers over the tubs. The tubs themselves are too small. Their dimensions are: Diameter 12ft. 8in., and depth to false bottom 35in. This gives a capacity of about 14 tons when the vat is filled to within 6in. of the top. The diameter of the vats should be increased, but not necessarily the depth, since the capacity for leaching in a given time increases in the direct ratio of the surface areas, while increasing the depth increases the length of time necessary to leach a charge in direct ratio to the increase. Beyond certain limits increase in either diameter or depth is not practicable, but tanks holding 25 to 50 tons are within the limits of economical and convenient work.

As would be expected from the crudity of the crushing at the Mercur mill, the time of leaching necessary to extract all of the gold that is possible varies greatly. It ranges between 10 and 240 hours. Such wide extremes cannot be due to the nature of the ore alone, but to the differences in mechanical condition. It is claimed, moreover, that the ore is singularly constant in quality and value. The precipitating-boxes are 40ft. long—one of wood, and the other, slightly larger, of iron. Through these boxes the solution from the tanks passes constantly, and is returned to the stock solution tanks, where additions of cyanide are made to bring it up to the proper strength. After the ore in the tanks has been leached sufficiently, the tank is allowed to drain. However, a considerable quantity of solution (about 400lb. to the ton, or with the 0·25-per-cent. solution used at the Mercur about 1lb. of c. p. potassium-cyanide to the ton of ore) remains in the tank. Of course, it is imperative that as much of this as possible should be saved. To dislodge this, wash-water is used, either plain water or, by a system employed at times, weak solution resultant from washing. In the latter case the weak solution is stored in separate tanks, and this arrangement allows washing with a minimum increase or wastage of solution.

The auriferous precipitate at the Mercur is remarkable for its high contents in lime, as it carries 36·7 per cent. Ca CO_3. The ore is highly calcareous, but so great a solubility of limestone in cyanide as this would imply is to be doubted; it is probably due to mechanical causes, finely-divided ore being carried in suspension into the precipitating-boxes, where it settles. This, of course, would make the precipitate difficult to handle did the company attempt to refine it on the spot, but as it is shipped to smelting-works, the latter have to contend with this difficulty.

The smelting-works pay a very fair price for the gold. They allow £4 an ounce, less express charges of 6d., the gold in the precipitate thus netting £3 19s. 6d. per ounce troy.

The extraction at the Mercur has varied. When the mill was first put in operation it was considerably below 70 per cent., but, as experience with the process increased, the results became more encouraging, until now the average return is between 85 and 90 per cent. The mill has been enlarged recently, and better results are anticipated both as to extraction and cost. The cost during an early period of work is given at 9s. 8d. per ton, divided as follows: Potassium-cyanide (1·27lb. per ton), 2s. 9d.; zinc (0·55lb. per ton), 2d.; labour (seven shifts per twenty-four hours, six day and one night), 4s. 5d.; supplies, repairs, fuel, freight, 2s. 4d.; total (not inclusive of office-expenses, royalty, and superintendence), 9s. 8d.

Since this period the expenses have been reduced, as the amount of cyanide lost per ton has been diminished, and a larger amount of ore is reduced with the same amount of labour.—*Engineering and Mining Journal.*

THE McCULLY ROCK- AND ORE-CRUSHER.

Among the machinery exhibits at the Chicago Exhibition there was one from the McCully Rock- and Ore-crushing Company, of Philadelphia, of which a sketch is annexed. The shaft and crusher-head are suspended, and adjusted entirely from the top of the machine, the point of least movement or gyration of the shaft thus diminishing the supporting friction of the shaft and crusher-head to a minimum. Its shaft has upper and lower line-bearings corresponding to its set angle; and, as this angle is never changed, all adjusting friction due to change of the shaft angle, and consequent finding or wearing of new bearings by the shaft when adjusted, and the increased consumption of power during the finding or wearing of such new bearings by the shaft, are avoided. It has

a manhole or large opening in the lower casing section for access to the lower shaft-bearing and the actuating mechanism for oiling the same while the machine is in operation without danger to the attendant; hence there is no loss of output due to stopping the machine for oiling. It has a removable bottom supporting the lower shaft-bearing with its actuating mechanism, so that all of said parts can be easily and quickly removed from the machine for repairs or replacement, and be correspondingly returned without dismantling the shaft, crusher-head, or other parts of the machine.

In Figs. 1 and 2 the top-plate B has a central hub-bore (*b*), with bottom flange b^2, upon which rests the sleeve b^3. The bore *b* may taper outwardly, from below upwardly corresponding to the angle or incline of the shaft C; or said bore may be cylindrical, and the outside periphery of the sleeve b^2 taper from below upwardly, corresponding to the angle or incline of the shaft, as shown in Fig. 2. Two superposed steel nuts D D^1 on the end of *c* of shaft C above sleeve b^2 support the shaft at its upper end. The upper nut D is shown provided with a key *d*. In either case, the nut with the key is the adjusting nut, and the threads of the upper nut D alone support the weight of the shaft and the downward pressure incident to crushing. The other nut is the locking nut for the adjusting nut, and both are tightly screwed up so as to be rigid on the shaft to prevent all wear. The support, therefore, never wears loose. In Fig. 1 a single cap or cover b^4, and in Fig. 2 a double or sectional cap or cover b^4, are shown for obtaining access to the nuts D D^1, and for supplying oil to chamber *e* in bore *b*, in which chamber is an annular outer feather-edge ring e^1 for directing away from the shaft any grit or dirt, and for graduating the supply of oil to the bearings for sleeve b^2 in bore *b*. A thin steel washer c^1 rests loosely on top of flange b^3, and steel sleeve b^2 is on said washer; the sleeve measures from 11in. to 12in. long, and the thickness of its shell is from 1¼in. to 2¼in.; this depends on the size and weight of machines. The sleeve b^2 has its bearings in the hub-opening *b*, to correspond with the incline of shaft C, and angle or incline of eccentric bearing at bottom, and the sleeve is bored to fit shaft nicely. The shaft has a screw movement in the sleeve b^2, of from 6in. to 7in. up or down, as may be necessary to adjust for the degree of fineness required, or take up for wear of crushing-faces. At same time, when it is down to the lowest point, there is then not less than from 5in. to 6in. of solid shaft without screw, inside of said sleeve. This prevents the screw-threads from cutting the bearings inside the sleeve.

It will be seen that all the weight of the shaft and crusher-head, together with the downward pressure when crushing, all rest on the nut D, sleeve b^2, washer c^1, and is finally all supported on the annular flange b^3 at the bottom of the hub; this being the centre of movement, or point of fulcrum, there is very little motion of the shaft. The sleeve b^2 gyrates with the shaft, which gives it a rolling or travelling movement on its bearing, and also on washer c^1 on flange b^3. By this improvement, as there is no rubbing or sliding, all unnecessary friction is avoided, and very little oil is required at this point, which in this machine never heats. The shaft being cylindrical, and of uniform thickness at top and bottom ends, it makes no difference as to the distance it may move up or down; the line of bearing at top and bottom never changes, and the point of fulcrum is always in the same position. Shaft C swings freely as a clock pendulum, and without friction, the eccentric hub F forcing it to gyrate. The bearings here move in a bath of oil, and, having no unnecessary friction, will never heat if properly oiled. The engine-power is all exerted directly on the rock being crushed.

The lower section of the machine is constructed with a large opening or manhole, with a close-fitting cover or door, as shown in figure, for the purpose of giving free access to the actuating gear and bottom bearings for adjusting, fitting, and oiling at pleasure. The outer eccentric bearing is oiled direct through said opening by means of a cup having a pipe-connection with oiling-chamber L. The collar K answers as a dust-protector for the bearings. This collar does not revolve with the gear-wheels, but moves with the gyration of the shaft, consequently the oil is not thrown out of the cup. It is attached to and gyrates with the shaft by a hook and chain connection *k*, which allows the shaft to slide freely through the collar K when adjusted from the top of the machine. G represents a hood or cover of canvas or other flexible material, having an annular ring fastened to the bottom of same and resting on the outside ring of collar K, and fastened rigidly to the shaft at *g*. The cock *l*, at the bottom, is for drawing off the oil if required to wash out or make changes, and l^1 is the overflow-pipe leading to a suitable overflow receptacle outside of the machine; *n* represents a key set rigidly in shaft G and a corresponding key-seat in crusher-head n^1, so that the latter will pass down said key; this prevents the crusher-head from passing down below the proper position, and also any horizontal movement; and n^2 shows the fastening-keys and ring at the top of the crusher-head to prevent it rising on the shaft.

The machine is made in nine sizes, No. 1 having a capacity of from 4½ tons to 8½ tons per day, while No. 9 can crush from 120 to 170 tons in the same time.

NEW CHLORINATION PROCESS.

Notwithstanding the progress made in the methods of gold-extraction, based on the solvent action of the alkaline cyanides, the old process of chlorination still finds favour with many companies. At Mount Morgan Mine, Mr. J. Sutton, of Brisbane, has recently completed a long trial of a modified cholorination process, which, for economical working, seems to put the recovery of gold by chlorine once more in the front rank. The chlorination plant used in these trials consisted of a wrought-iron barrel lined with lead, through which passed axially a perforated tube lined with asbestos. Attached to this barrel was a smaller one, also lined with lead, and fitted with a steam-jacket in such a manner that both barrels could be rotated by the same gearing at the rate of about five revolutions per minute. The damp ore is placed in the large barrel, and a charge of manganese, dioxide, salt, and sulphuric acid in the smaller one, before commencing operations. In this way the ore, as

it is rotated in the large barrel, is saturated with chlorine as it issues from the central tube; and when the evolution of gas becomes slow, steam is turned on to the jacket, and thus ensures the complete decomposition of the salt. Valves in the barrel are opened at starting, so as to allow the exit of the enclosed air and guarantee a strong chlorine gas acting on the ore. Three hours' treatment has been found sufficient for the dissolution of the gold in the Mount Morgan ores; and at the end of this time the contents of the barrel are run into a leaching-machine, which is a centrifugal pan similar to that used for drying sugar. This method of leaching is found to be most economical of water, and seven minutes only are required for leaching a charge of from 10cwt. to 20cwt. of ore. At the end of the leaching-operation, a small mechanical plough removes the spent ore from the centrifugal machine into trucks or into chutes leading to the waste-tailings heap. The gold is recovered from the solution in a precipitating-tank of rectangular shape, through which a spindle is driven from corner to corner. Kerosene oil and sulphate of iron are added to the leachings in this tank, and the precipitation of gold is completed in ten minutes. A tap in the precipitator is then opened, when the water and base metals run through a sand filter, and the oil containing the gold in suspension passes into another small centrifugal, where the oil is immediately separated and ready for use over again, while the gold remains in the basket, from which it is scooped out and melted. Those acquainted with the Hall and Richard process, which hitherto has been in use at Mount Morgan, will see that the new process has many points of dissimilarity to it, and saves not only the bother of attending the burning of the charcoal filters, but also marks a great improvement in the methods of leaching. In addition, no amalgamation, as the gold separated from the oil is ready at once for the melting crucible; and the ore, unless it contains a large quantity of mundic, can be treated without any previous roasting, since the chlorine is delivered to the ore in an undiluted condition. The cost of chlorination by this process is stated to be 6s. per ton.

THE RIO TINTO ROCK-DRILL.

This rock-drill, on exhibition in the British Section of the Machinery Hall, at the World's Fair, first came into notice at the International Exposition of Mining and Metallurgy, held at the Crystal Palace in London in 1890, where it gave an excellent account of itself at the drill contest held in connection with that Exposition mentioned. Mr. James McCulloch, the inventor and patentee, is a practical mechanical and mining engineer, and twenty-two years ago was engineer to the Burleigh Rock-boring Company, afterwards carrying out on his own account many rock-drill contracts in mines throughout Europe; he has now been for ten years with the Rio Tinto Copper-mining Company in Spain, carrying out contracts for the development of their mines.

The advantages claimed for the Rio Tinto Rock-drill are speed and economy in tunnelling, driving headings, benching, shaft-sinking, rising, stoping, and quarrying; and when two or more of these drills are mounted on the tunnel car, headings can be quickly driven. Its great efficiency is the result of the construction of its working-parts which include an absolute, positive, valve-motion; reliable twist gear; a cradle quickly and easily adjustable; durability and boring-power, and a total absence of springs. The positive valve-motion is obtained by the combined action of the air or steam-pressure and a tappet actuated by the piston-rod, which imparts at each stroke a definite movement to the valve; but this tappet has a very small amount of work to do, because, as soon as the valve is started from its end position, steam or air is admitted into the valve-chest and helps to push the valve over; once over, the top and bottom parts of one end of the valve-chest are open, and shut at the other end, thereby keeping the valve in its position until the tappet again starts the valve. This overcomes the risk of operating the valve by air-pressure alone, and of its stoppages by grit or rust. No springs are required at the back of the valve to keep it in position, as the pressure does this, being equally distributed over the whole of the valve.

The second and most important advantage claimed is the twist-gear device used, which dispenses altogether with ratchet-wheels, pawls, and springs, and is claimed to be simple, durable, and certain in action, no matter what class of work it may be doing, or at what rate of speed the drill is running, or how long or short the stroke may be; the twist is as perfect with a 2½in. as with a 5½in. stroke, and is most effective when starting upon uneven rock. A circular hole can be formed with the short stroke at a speed of 600 per minute. To do this, Mr. McCulloch has provided for the automatic movement of a non-rotating toothed disc relatively with a tooth disc fixed on the twist-bar, for the purpose of pulling it into and out of gear. This is actuated by the pressure of air or steam diverted through a passage made for it running longitudinally with the cylinder; when the air or steam enters the lower or outer end of this passage at bottom of cylinder to cause the piston to make its return or rotating-action stroke upward, it moves the non-rotating toothed disc forward about $\frac{5}{16}$in., becoming thereby geared with the rotating disc on the twist-bar and holding it firmly while the piston-rod rides or twists upon the bar. During the forward stroke of the piston, when the piston-rod is striking its blow, the two discs are out of gear, avoiding unneccessary stress on the discs and friction upon the twist-bar. The rotation being precise and accurate, no injury can be done to either gear or twister, both being relieved of concussion and friction.

The last advantage claimed for the Rio Tinto drill is the special provision made for taking up the wear in the cradle and keeping the machine steady when at work, dispensing with the necessity of removing the cylinder and the employment of skilled labour to adjust the cradle. This is done by making the cradle in two longitudinal parts, held together by studs or bolts. Numerous thin strips of steel are inserted between them, which can be taken out as the cylinder wears, and close together the two halves of the cylinder by screwing up the bolts. Any unskilled workman can readily adjust the cylinder in the cradle so as to keep it steady and rigid while the drill is in operation. The best class of design, workmanship, and materials is employed in the construction of this tool.—*Engineering and Mining Journal.*

ELECTRIC ROCK-DRILLS.

Description of the Electric Rock-drilling Machinery at the Carlin How Ironstone Mines at Cleveland.*

(By Mr. A. L. Steavenson, of Durham.)

Ironstone mining in Cleveland has now extended over a period of 40 years, during the whole of which the writer has been connected and conversant with its progress.

Mining by Hand-labour.—Hand-labour has been the general custom, and during the first five-and-twenty years, when skilled men were scarce and new-comers had to learn the work, it was usual for a skilled miner to take a novice with him as an underhand to break up and fill the stone, paying him a datal wage varying from 3s. 6d. to 4s. per shift. These underhands were known amongst the miners as "hagmen." The skill of the miner being exercised in getting as much stone with as few holes and as little powder as possible, the holes are drilled of a three-cornered section by the miner giving the drill a slight turn between each blow; they vary from 3½ft. to 4½ft. in depth, depending upon the backs or natural vertical cleavages in the stone. To drill a hole of 3½ft. requires about half an hour of steady work; the powder used is about 6oz. per ton of stone, and the usual price of getting from 10d. to 1s. per ton. Gradually, as the supply of skilled men overtook the demand, the two miners in each place shared the work and money between them, each man making 4s. 6d. to 5s. 6d. per shift.

Hand Ratchet-drill.—During the last few months hand-drills, made to revolve by a ratchet, have been introduced, the work being divided between the skilled miner and the filler. These drills promise good results in cases where machines are not available; but the question of prices is not yet definitely decided.

Compressed-air Rotary Drill.—About sixteen years ago Mr. William Walker, of Saltburn, introduced a rotary drill worked by compressed air. Of these the writer procured four; and by working double shift, and employing one skilled man to work the drill and another to fire the shots, with unskilled labour to do the rest, he has effected considerable economy. At the Skelton Park mines of Messrs. Bell Brothers these machines continue doing good work. The writer has always insisted upon the necessity for adopting the Colladon system of cooling the air by water spray during compression; but, notwithstanding the marked economy resulting therefrom, the great leakage arising from the length of pipes of various sizes, which amounts in this case to about eight miles, and from the consequent large number of joints, seemed to present an opportunity for improvement by the use of hydraulic power.

Hydraulic Drill.—At the Lumpsey mines, therefore, where there was a large body of water tubbed back in the shafts 600ft. deep, the writer designed a hydraulic drill to utilise this water, carrying pipes into the face of the working-places. The pressure of 250lb. per square inch at the shaft bottom was utilised at the drill by means of a small turbine made by Messrs. Gilbert Gilkes and Co., of Kendal, and placed on the machine. This plan has given excellent results; but, as the water has to flow back to the shaft bottom, it can only be used in places to the rise; and, moreover, it involves the cost of water-mains to convey the pressure.

Petroleum Engine.—The writer next introduced the petroleum engine of Messrs. Priestman, and a drill suited to its conditions. Five of these are now in use, and have done good work.

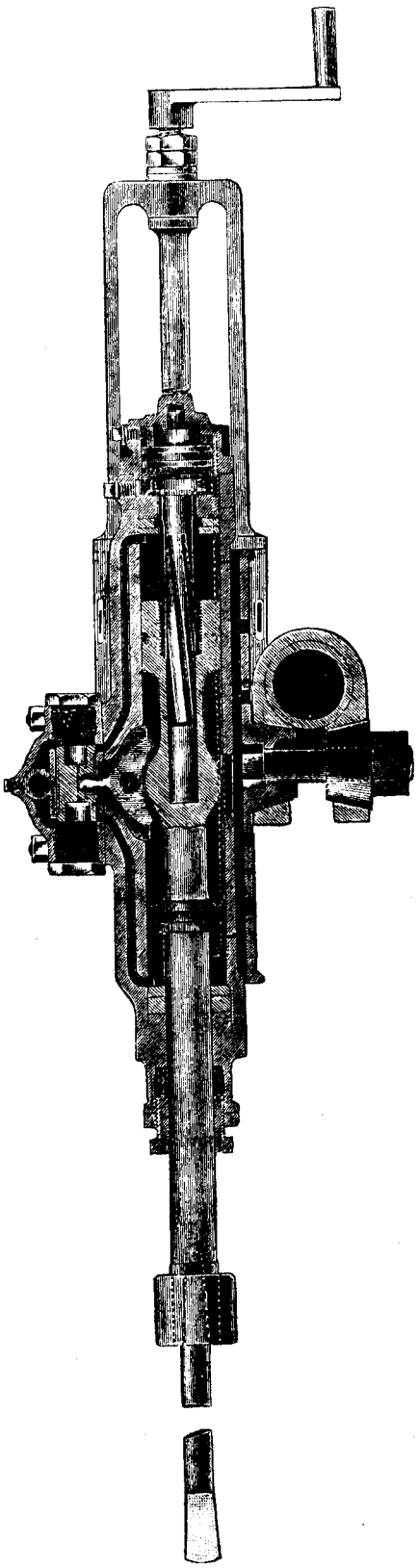
Electric Drill.—When electricity became applicable, its simplicity and regularity in working seemed to offer an inducement for a trial. With the assistance of Mr. Robert Clough, engineer to the mines and collieries of Messrs. Bell Brothers, the writer designed a drill to be worked by this power.

Dynamo.—The current for working the drills is generated at bank by a compound-wound dynamo, having an output of 20,000 watts, and capable of furnishing a current of 50 ampères at a pressure of 400 volts when running at 900 revolutions per minute. This dynamo is intended to supply current for working the first section of the plant—namely, three drilling-machines. The current required to drive each drill varies, of course, with the hardness of the stone the drill is working in; but it may be taken that, under ordinary conditions, and when the voltage at the drills is 300, the current absorbed per drill-motor is about 15 ampères, which is about six electrical horse-power; and when a dynamometer was applied to the drill-bar, six-horse power was obtained. The current from the dynamo is taken to a high-tension double-poll switch on the main switch-board, which is of enamelled slate and has mounted upon it the necessary fuses, measuring instruments, &c.

Cables and Junction-boxes.—From the switch the current is conveyed down the pit through cables covered with highly vulcanised indiarubber. The cables are run all the way in-bye on insulators, and are kept well in sight, so that, should a fall of stone occur, the damage can be quickly discovered and set right. The main cables are run to a point at a distance of 1,000 yards from the generator; and then from this point branch cables are run to the different junction-boxes, of which there are six to each drill, commanding twelve working-places. The junction-boxes were specially designed to meet the exigencies of the case by Mr. Bigge, and are really a combination of a junction-box switch and connecting-plug, as shown in Figs. 1 to 4. The plug is locked in position by a pin, and cannot be withdrawn without first of all lifting the switch, thus preventing sparking and wear on the contacts. Each district to be worked by the several drills is completely wired out, and fitted up with these junction-boxes, so that when the drill is moved from one working-place to another a box is always to be found within 50 yards distance. The plug at the end of the drill-cable is then inserted, the switch on the drill turned on, and within a few seconds the drill is again at work. Much time is saved by this method.

Drilling-machines.—As shown in the accompanying drawing, Figs. 5 to 7, the way in which the electricity is applied is neat and handy. The motor M is used not only to drive the drill gear, but also to act as a counterbalance to the weight of the drill itself and its gearing. The motor

* Paper read before the Cleveland meeting of the Institution of Mechanical Engineers.



THE RIO TINTO ROCK DRILL.

ELECTRIC ROCK DRILLS

Fig.1.

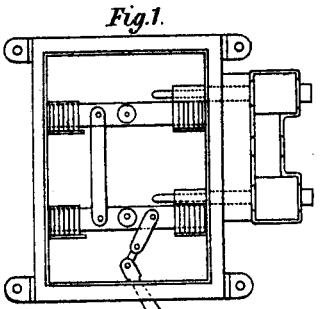


Fig. 2.

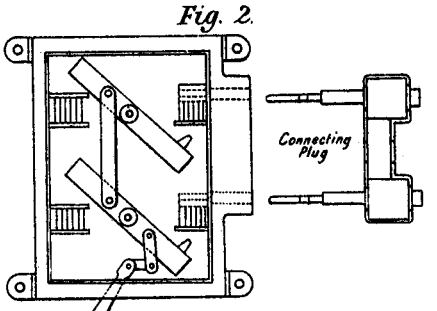


Fig.3

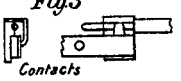


Fig.4.

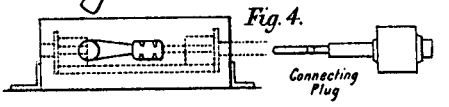


Fig.5

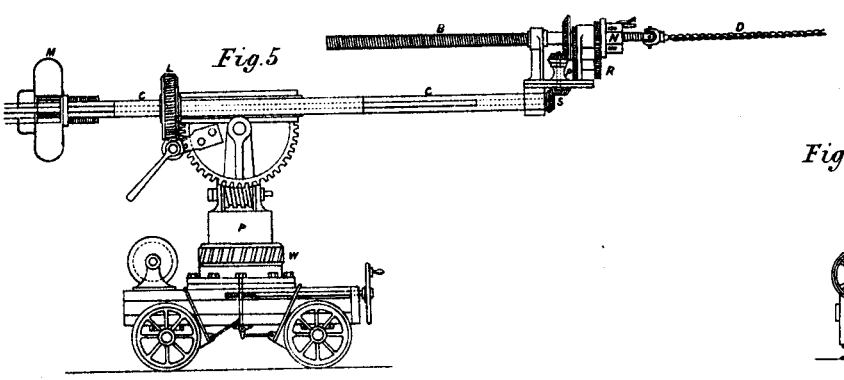


Fig.6.

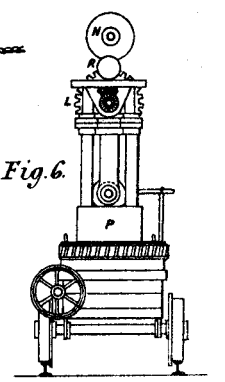


Fig. 7

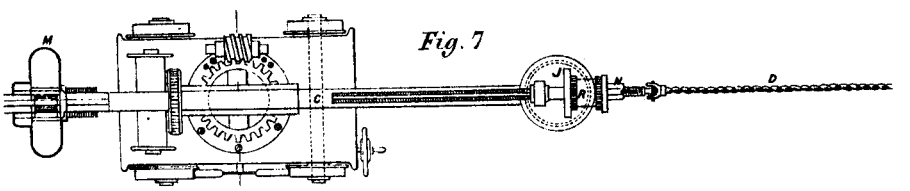
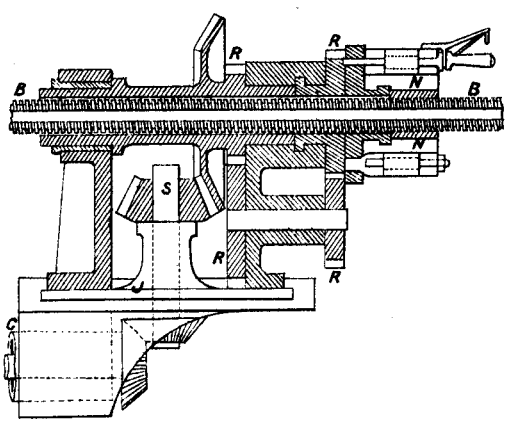
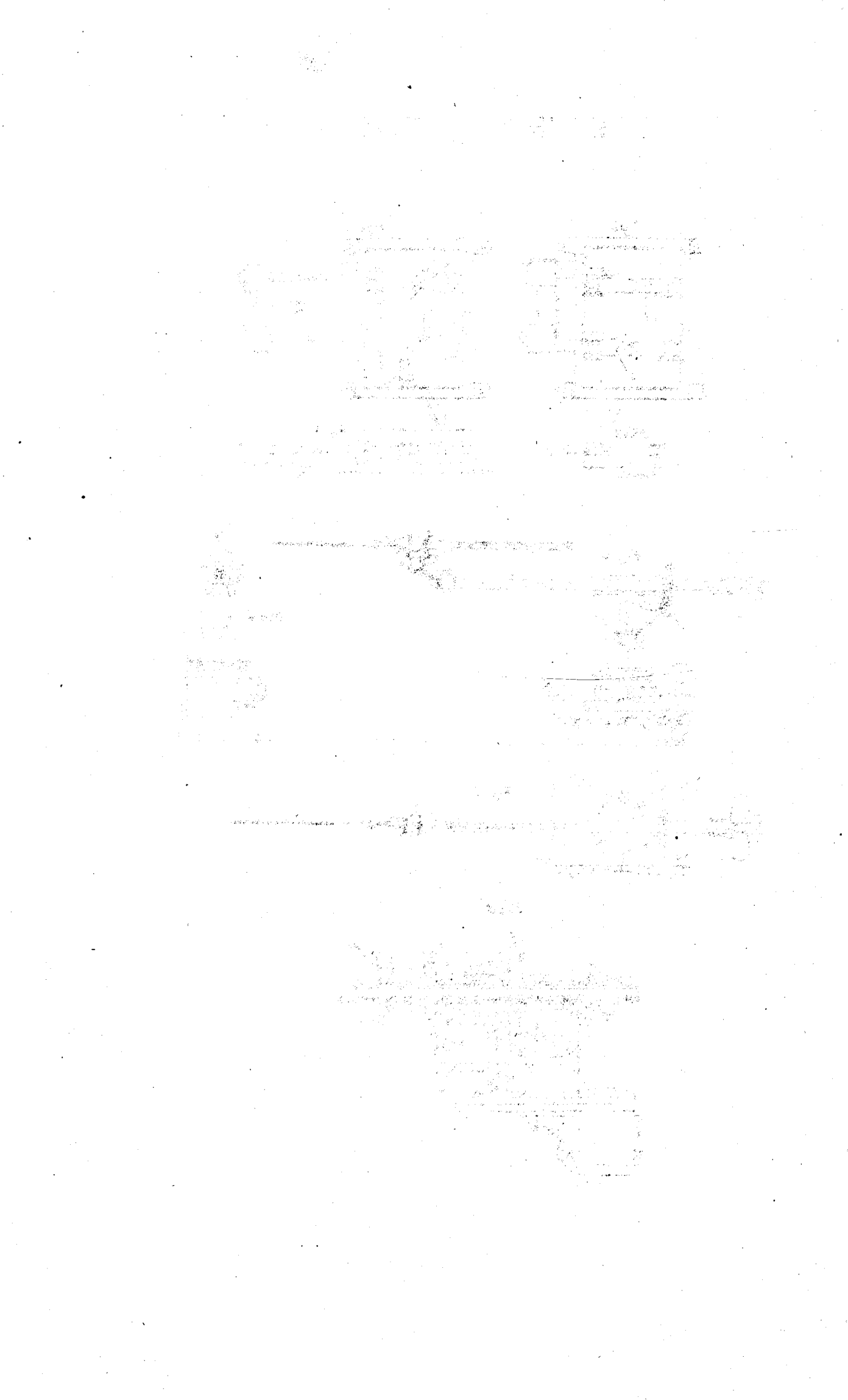


Fig.8





rotates a shaft which passes through the long hollow carrying-bar C, and by a pair of bevel wheels causes the vertical spindle S to revolve, and a bevel pinion on the top of the spindle, gearing into a bevel spur-wheel on the boring-bar B, rotates the drill D. The forward feed of the boring-bar is governed by two pair of retarding-wheels RR, Fig. 8, which are geared in such a proportion as suits the nature of the stone. The drill is carried on a circular bed-plate J, which is mounted on the end of the carrying-bar C, and can be turned round by hand when the binding-screw is released. As soon as a hole has been drilled the full length of the screw on the boring-bar B the split nut N is opened and the boring-bar drawn back for inserting a longer drill. In order to reach different heights, the drill can be tilted upwards or downwards by means of the semi-circular arc A, which is moved by a worm. By another worm-wheel W, the upright pedestal P can be turned horizontally round its centre. A third worm-wheel L turns the long hollow bar C which carries the drill.

Motor.—The motors on the drills are shunt-wound, and can easily utilise a current of 20 ampères at 300 volts pressure, giving off about 95 per cent. of what they receive. They are of the Goolden enclosed kind for mining purposes, both the armature and the commutator being completely enveloped in gun-metal cases, which are both gas-and dust-tight. Even should water pour over them, or a fall of stone occur, they are perfectly protected, and no appreciable damage would be done to them. The brushes used are of special carbon, coated with copper. The feed for the brushes as they wear themselves away is automatic, so that they can be run for weeks together without requiring any adjustment or attention. Each drill is provided with a starting-switch, placed in the most convenient position on the drill-carriage itself, and arranged with resistance-coils in such a manner that the drill can be started gradually, and stopped either gradually or instantaneously. Each drill is also provided with a reel of 50 yards of twin flexible cable for the supply and return of the electricity; at the end of the cable is a connecting-plug for inserting into the nearest junction-box.

Working.—These electric drills were put into the hands of men who had no previous knowledge whatsoever of electricity, and the day the first drill was put into the mine it was at once set to work at the face, and has been at work ever since. The men are now thoroughly accustomed to the drills, and handle them with the greatest ease. The writer has thus tried almost every method for working drilling-machines in ironstone mines, including compressed air, hydraulic power, and petroleum engines, and it is his decided opinion, as the result of this practical experience, that for simplicity in working, ease of transport, speed, facility for extensions, and economy in working, the electric drill has proved itself to be in advance of any other mechanical contrivance yet introduced; and that in the future, where power has to be conveyed to any considerable distance for mechanical drilling, electricity will undoubtedly play the predominant part. The entire work was placed in the hands of Messrs. D. Selby, Bigge, and Co., electrical engineers, of Newcastle-on-Tyne; and Mr. Bigge devoted considerable time with the writer and Mr. Clough to working out and improving the various details of this the first attempt at electric drilling in the Cleveland ironstone mines.

Output.—The joint output for one week for two of the three machines has already reached 1,577 tons with 790 holes. From 80 to 100 holes have frequently been bored with one machine in a shift, each hole averaging about 4¼ft. deep. The miners are enabled to earn 7s. 7d. per shift, while the stone is got at a cost of 7¾d. per ton. Powder is always from one-third to one-half more costly when drilling-machines are used than is the case with hand-labour, since it suits better to blow the stone out with a large number of holes which are quickly and cheaply drilled; this plan also makes the stone fall in smaller blocks, and so saves labour in breaking them up previous to filling.

General Results.—In attempting to compare the results obtained with the several drills, the following considerations have to be borne in mind: The conditions of the seam of ironstone affect the output and cost. An open stone admits of fewer holes in one place. Then time is lost in more frequent removals of the drills, and the number of holes drilled per hour is diminished.

The cost of the machine itself sometimes represents the whole, and sometimes only a fraction, of the total cost. Thus, a petroleum-drill covers the entire cost of its adoption. But the compressed-air drill in some cases has attached to it an average of more than a mile of pipes, and also requires its engine and compressors, as well as its share of boiler. The electric drill also requires engine and dynamo, with a length of cable depending upon the distance from the shaft; it is still so new that alterations and improvements are being made, as experience is gained. The hydraulic drill, although getting its power from natural sources, needs pipes; and the exhaust-water has afterwards to be pumped up to the surface. The hand rachet-drill has been applied as yet in only one or two mines, and the tonnage rates and system of working are not yet finally settled with the workmen.

Subject to these considerations, the following comparative statement may be taken to represent generally the results thus far obtained with the several drills:—

Description of Drill.	First Cost of Machine.	Holes Drilled per Hour.*	Ironstone got per Shift.
	£		Tons.
Hand jumper	...	4½ft. in 45min.	5 to 8.
Hand rachet-drill	3	Not yet known	About 18.
Compressed-air drill	250	About 8 holes	100 to 130.
Hydraulic turbine	220	About 8 holes	100 to 130.
Petroleum engine	375	About 8 holes	100 to 130.
Electric drill	350	About 10 holes	140.

* This includes the time lost in moving the machine to different working-places.

The length of shift is eight hours from bank to bank, or, say, seven hours at the face. At the Park mines the drills work two shifts in twenty-four hours, and at the other mines one shift, and six shifts per week when trade permits.

AUSTIN'S PATENT AMALGAMATOR.

Austin's amalgamator consists principally of two parts—viz., a column A, and quicksilver cell B. It is built over a furnace F. Through the quicksilver cell and at right angles to the current are placed tubes 1, 2, 3, 4, 5, 6, 7, 8, 9 (the number of tubes in proportion to the size of machine). These tubes are placed zig-zag, and perform a twofold duty—viz., as a means of heating the silver, and for the purpose of splitting up the current, whereby a more complete amalgamation takes place.

The heat passes under the machine F, through the tubes 1, 2, &c., over the top of the cell G, and up the chimney H, whereby the silver is kept at a sufficiently high temperature to cause a quick amalgamation; besides, the action of heat prevents the sickening of the silver, and loss by pulverization.

A director D forces the detritus through the silver by gravitation—the column allowing 13·6in. of water for every inch of silver, although when the silver is warm its density is considerably reduced; hence, not so much pressure is required—another point in favor of heating the mercury.

The detritus is received in the hopper, passes down column A, below the director D through silver, through the cell B, over and under the zig-zag tubes afore-mentioned, finally below the depresser E, and up through the silver, and out of the discharge-lip C. By the arrangement of tubes and the construction of the cell—the director and depressor—every particle of the stuff treated must come in contact with the silver. The arrows show direction of the current. Tap I draws off the silver to retort.

The *Maryborough and Dunolly Advertiser* writes as follows as regards this amalgamator:—

"A new invention, patented throughout the world by the inventor, Mr. T. R. L. Austin, of Talbot, promises to perform what the numerous prior inventions have tried to do—viz., save all free gold (especially float and flour gold) from battery tailings, puddling-machine slum, alluvial tailings, surfacing, and other auriferous material. The invention consists virtually of one part, but for convenience it is divided into a column or chute and a quicksilver cell. The machine is automatic in working; and, as all the parts are fixtures, there is no danger of anything getting out of order. The amalgamator is built over a furnace, and is so constructed that the heat passes under the silver, through it by means of tubes (like a multitubular boiler), and over the top of the silver, whereby the quicksilver in the cell is kept at a sufficiently high temperature to more readily amalgamate with the gold. For feeding the machine, the detritus passes into the vertical column, and by the force of gravitation is carried through the warm quicksilver downwards for 3in., through it longitudinally for 18in., and finally up through 3in. before it discharges itself. The construction of the cell is of such a nature that all material must pass through the silver, and in a distributed state, so that there is no possibility of any free gold escaping. The capacity of the amalgamators that are already made is about 1 ton an hour, but they can be made to take a much larger quantity of stuff in that time. The machines can be put on a dray, carted to a tailings or slum-heap, and erected ready for work in eight hours. For live battery sand or slum running from puddling-machines, Mr. Austin claims the saving of copper-plates and blankets (a considerable item in expenses). One man can supervise ten machines of the capacity of 1 ton an hour, which is at once an important saving in labour alone. The expense of the patent amalgamator is a royalty of £1 per week for machines of 1-ton an hour capacity, and the inventor asserts that *débris* containing 1dwt. to the ton will pay well. For the present-sized machines there must be at least a 2in. pipe to supply water if working on a dead sand or slum heap, but on a battery or puddling-machine constantly at work there would be sufficient water coming with the *débris*. The following trials have been made, which show its efficiency for saving all gold that escapes from batteries or puddling-machines:—

"No. 1 trial: Parker's United Quartz-mining Company, Gordons, after passing over Chinese tables, the return was 12dwt. for sixteen hours' work.

"No. 2 trial: At Egerton's Quartz-mining Company, Egerton, the return was 27dwt. for thirty-five hours from the sand-heap.

"No. 3 trial: At Talbot, 5 tons of slum gave a return of 7½dwt.

"No. 4 trial: At Talbot, ten tons of sluice-tailings gave 7½dwt. of gold. (The mine was so poor that work was stopped the following week.)

"At the Gordon Mountain Gold-mining Company, Bonnie Doon, last January, Mr. Austin competed with the Wheeler's pans—First trial: 9½ tons through Wheeler's pans gave a return of 17dwt. smelted gold; 9 tons from the same hopper, and at the same time passed through the Austin amalgamator, gave a return of 22dwt. smelted gold. Second trial: Wheeler's pans, 20 tons cleaned up for 9dwt. of smelted gold; Austin's machine, from the same hopper and at the same time, put through 20 tons for a return of 1oz. 2dwt."

PATENTS APPLIED FOR IN THE COLONY.

SPECIFICATIONS.

IMPROVEMENTS IN OR CONNECTED WITH CRUSHING- OR GRINDING-MILLS, MORE ESPECIALLY INTENDED FOR GRINDING OR REDUCING ORES CONTAINING PRECIOUS METALS, AND FOR SEPARATING METALS THEREFROM BY AMALGAMATION.

I, Emma Matilda Shill, of 84, East Dulwich Road, East Dulwich, in the County of Surrey, England, widow and administratrix of the estate of Richard Edmund Shill, late of 49, Crystal Palace Road, East Dulwich, in the County of Surrey, England, Engineer, deceased, do hereby declare the

nature of the invention for "Improvements in or connected with Crushing- or Grinding-mills, more especially intended for grinding or reducing Ores containing Precious Metals, and for separating Metals therefrom by Amalgamation," and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to mills of the kind wherein grinding or reducing is effected by means of balls revolving upon a circular track.

The object of this invention is to so feed the ore or material to be ground or reduced that it is more efficiently acted upon by the balls than hitherto, and so that, in the case of grinding or reducing ores containing precious metals, the amalgamation of the precious metals is more thoroughly effected than hitherto, and the general arrangement of the mill is such that the grinding or grinding and amalgamating is or are very efficiently performed.

According to this invention I arrange the outlet or outlets from the passage or passages, by which the ore or material to be acted upon is passed into the mill at a point near to the lower part of the balls and close to the race upon which they run, and so also that where amalgamation is to be performed the delivery is immediately over a bath of mercury situated close to the portion of the mill in which the grinding effect is obtained. The outlet for the ground ore or material from the mill is situated at a higher level than the aforesaid delivery, the object of this being to prevent float gold, or fine particles of gold, or fine portions of the ore or material which may contain gold, passing across the mill without being properly acted upon.

I will describe with reference to the accompanying drawing an arrangement according to this invention which I prefer, although I do not limit myself to the precise details. Figure 1 is a vertical section, and Figure 2 is a plan with the upper part and tray removed.

I provide a circular race A mounted upon suitable foundations or framing, having a driving-shaft B passing centrally therethrough. This driving-shaft B carries at its upper part a boss C, connected to a tubular piece D, through which the ore or material is fed into the machine.

This tubular piece D, at its lower part D^2, extends outwards in the form of a frustrum of a cone of such a size that it leaves a space d between its inner surface and a portion of similar formation at E, forming the inner part of the main structure, which carries the race, and leaving at its lower part an opening d^2, which is situated close to and above the portion of the race, against which the lower parts of the balls F bear. The outlet from the mill is situated preferably at a level about or above that of the centre of the balls, as shown at G.

The balls F are driven by means of anti-friction rollers b, carried by arms b^2, bolted or secured to lugs d^3, formed on the exterior of the aforesaid conical part D^2.

The weight of the balls F may be supplemented by means of a tray I for containing weights, the said tray I bearing, at its lower part, on the top of the balls F, and being fitted so that it can revolve round the tubular piece D aforesaid, and yet be capable of rising and falling thereon.

When amalgamation is to be effected, a trough J for containing mercury is situated immediately beneath the delivery-opening of the aforesaid conical part D^2, and in close proximity to the portion of the race upon which the lower parts of the balls act. When the machine is in operation the material, which has been previously reduced to a sufficiently-divided condition, is fed into the tubular piece D aforesaid, and passes down through the space d inclosed by its conical part, and is delivered at, or about level with, the lower part of the balls F. As water or other liquid is fed in with the material to be operated upon, and thus rises in the machine to the level of the outlets, which are preferably above the centre of the balls aforesaid, it follows that the delivery of the ore or material is always well beneath the level of the liquid in the mill, and cannot take a direct course across the mill without being properly acted upon by the balls, and where the mercury-trough J is provided it follows also that the precious metals in the ore or material are very efficiently subjected to the action of the mercury, thereby rendering amalgamation more complete. I find it advantageous to provide wings or vanes, as at d^4, on the inside of the conical part D, to act as stirrers on the water, to release any air there may be amongst the material being passed into the apparatus.

The parts most subject to wear, such as the race and the under part of the tray which bears on the balls, may be made with detachable bearing parts which can be renewed when worn. K is the feed-hopper; l, a lubricator; m, a blade for facilitating the ejection of the material by the outlet G; and n is a pipe by which I draw off water and sludge from above the mercury before opening the outlet n to draw off the mercury containing amalgamated gold.

Having now particularly described and ascertained the nature of the said invention, and in what manner the same is to be performed, I declare that what I claim is:—

1. In mills wherein crushing or grinding is effected by balls revolving on a circular track, an outlet or outlets by which the material to be crushed or reduced in the mill is delivered near to the lower part of the balls and near to the race on which they revolve, so that the said material cannot pass to the outlet from the mill without being first operated upon by the balls substantially as hereinbefore described.

2. In mills of the kind mentioned, and arranged as claimed by the preceding claiming clause, the combination of a mercury bath so situated that the material passing into the mill is fed directly over the said bath, and thence to beneath the balls substantially as hereinbefore described and illustrated.

3. In mills of the kind mentioned, the combination with the race and balls revolving thereon, and operated by rolling contact with drivers as described of a tray for containing weights, the said tray being independent of the drivers, and so mounted that it bears on the tops of the balls, and is free to have a rotary motion imparted to it by the said balls, whilst it is also free to rise and fall substantially as hereinbefore explained.

4. The arrangement of parts constituting a mill for grinding, or for both grinding and amalgamating, substantially as hereinbefore described and illustrated in the accompanying drawings.

Dated this 20th day of April, 1893. EMMA MATILDA SHILL.

An Improved Concentrator and Classifier.

We, Arthur George Holroyd, of Moray Street, South Melbourne, in the Colony of Victoria, metallurgist; Edward Hughes, John Sinclair Pirrie, and Edward Joseph Rigby, all of Hanna Street, South Melbourne, in the Colony of Victoria, engineers; do hereby declare the nature of our invention for "An Improved Concentrator and Classifier," and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention has been devised for the purpose of providing the public with improved apparatus or machinery for concentrating and classifying ores and metals, and, from the simplicity of its mechanism, is calculated to perform its functions with little wear-and-tear, and, generally, with greater facility and efficiency than has hitherto been obtained by other contrivances or apparatus having similar aims, whilst the whole of the operation of the machine is at all times open to the view of the operator in charge, thus permitting the fullest information to the said operator to satisfactorily adjust the supply of material to the machine, in order to obviate the mechanism working with too much or too little material.

In order that the invention may be better understood, reference may be made to the accompanying drawings, in which Fig. 1 is an elevation in section of our improved machinery. Fig. 2 is a plan of same, with a peripheral portion cut away in order to save space on drawing, whilst Fig. 3 is a detail view of a portion shown in dotted lines on Fig. 2.

In these drawings A represents a water-supply pipe provided with tap and handle A^1 and floating box A^2, A^3 is a water-supply tank arranged in such a manner that the small floating box A^2 may rise and fall for the purpose of operating the water-cock A^1. A^4 is a vertical pipe leading from A^3 down and into the horizontal frame B. This latter (see Fig. 2) is constructed in the shape of a cross, and serves a dual function—that is to say, to conduct the water coming from tank A^3 to the water-cocks B^1 and B^2, which latter are operated by handles B^3 and B^4, the purposes of which will be hereafter explained, and also to carry or support an annular channel C, said annular channel being provided with lead-away ducts C^1, and also to support the peculiar bent tube D. This latter tube D is provided at or near its under surface with perforations, and arranged in such a manner that when water is supplied to it from the cock B^1 the liquid will squirt out in the form of jets of spray for the purposes hereinafter to be explained. D^1 (see Fig. 2) are jointed tubes arranged in such a manner that they may be altered in a radial direction.

Referring to the tap B^2 (Fig. 1), it is arranged to supply water to an annular perforated tube E. F is a hopper (see Fig. 1) into which the ore-pulp or material is supplied, preferably in a wet state. From this hopper tubes or ducts F^1 lead the material into a semicircular V-shaped trough G, the latter trough G being provided at its bottom with outlet-holes, to enable the ore-pulp or material to escape, preferably along an annular bent director-plate G^1 on to a circular descending table H. The top of this circular table H is coated preferably with indiarubber or any other approved material, and the surface may be fluted or corrugated to suit local requirements. It will be seen by the drawings that this table surrounds an upright standard shaft I, but does not revolve with same, there being no intimate connection between the central plate H^1 of the table H and the said vertical shaft I.

Referring again to the table H (see Fig. 1), its lower edge terminates over the annular channel C, and the whole table is supported upon vertical flexible spring-plates J, which latter are secured to the floor as at J^1, and are connected to the underside of the table by pins J^2 and lugs J^3. An oscillatory and percussion motion is provided for on the underside of the table H (see dotted sketch on Fig. 2), and the working of which is as follows:—

Revolving motion is transmitted to the pinion-shaft K (see Fig. 1), on which is mounted a cam-piece K^1 (see Fig. 3), and so arranged that the curved lugs K^2 upon same strike and push back the striker-plate K^3 attached under and secured to the table H, and in doing so compresses a spiral spring K^4 (set in a rigid base frame K^5) in such a manner that immediately the point of K^2 has slipped off the point of the striker-plate K^3 the compressive force of the screw K^4 suddenly thrusts forward the plate K^8, and with it the table H, by virtue of the nutted rod K^6, the collar-block K^7 receiving the blow on frame K^5 produces percussion; the motion of the revolving cam K^1 being continuous, the table H is thus kept in a continued state of backward and forward percussive oscillations.

Referring again to the cross-frame B, revolving motion is imparted to it as follows:—

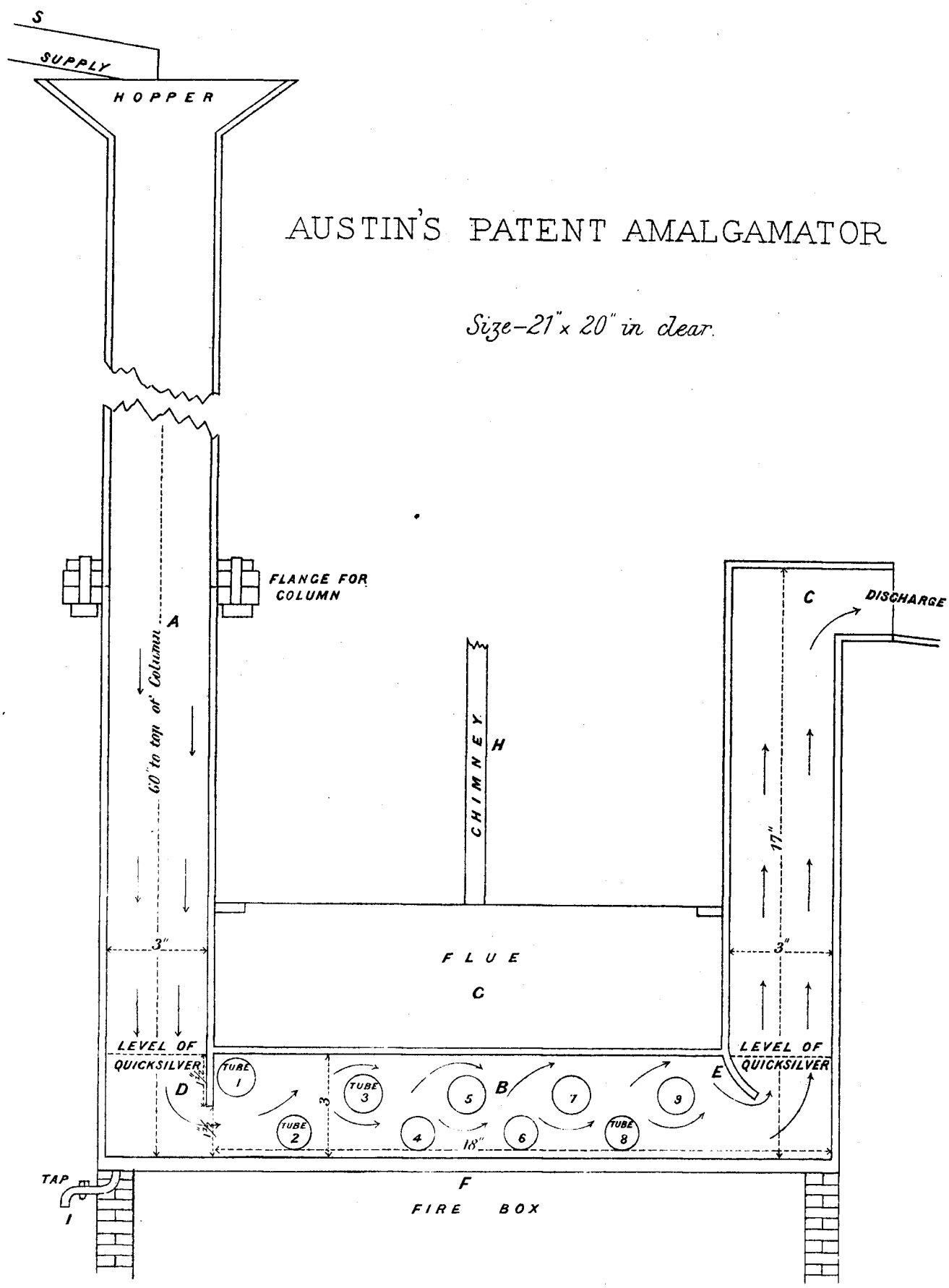
The shaft L (see Fig. 1) is put in action, and operates a worm-gear L^1 (see Fig. 2), and revolves a worm-wheel L^2, and with it the vertical shaft I, cross-frame B., the feed-trough G, and the annular channel C, the latter being connected to the frame B by the hanging rod B^5. A spur-wheel L^3 is mounted upon the shaft L to communicate with and revolve the cam-shaft K. N is a substantial standard or frame serving as a vertical bearing of the shaft I, and a horizontal centre bearing for a centre plate H^1 of the table H.

O and P are canals and pits respectively for the reception of the material and lead away of the sludge.

The *modus operandi* of our invention is as follows:—

Rotary motion having been imparted to the shaft L, and thence by the spur-wheel L^3 to the cam-shaft K, a continuous radial percussion motion is imparted to the table H, whilst the shaft I, frame B, receiving-trough C, feed-hopper F, and feed-trough G, cocks B^1 and B^2, curved tubes D and D^1, and annular pipe E all rotate in the direction shown by the arrows on Fig. 2. The ore-pulp or material is fed in to the hopper F, and proceeds down through the pipes F^1 to the semi-circular feed-trough G, through the perforations in the bottom of the latter, and thence along the guide-plate G^1 on to the table H in a continuous delivery.

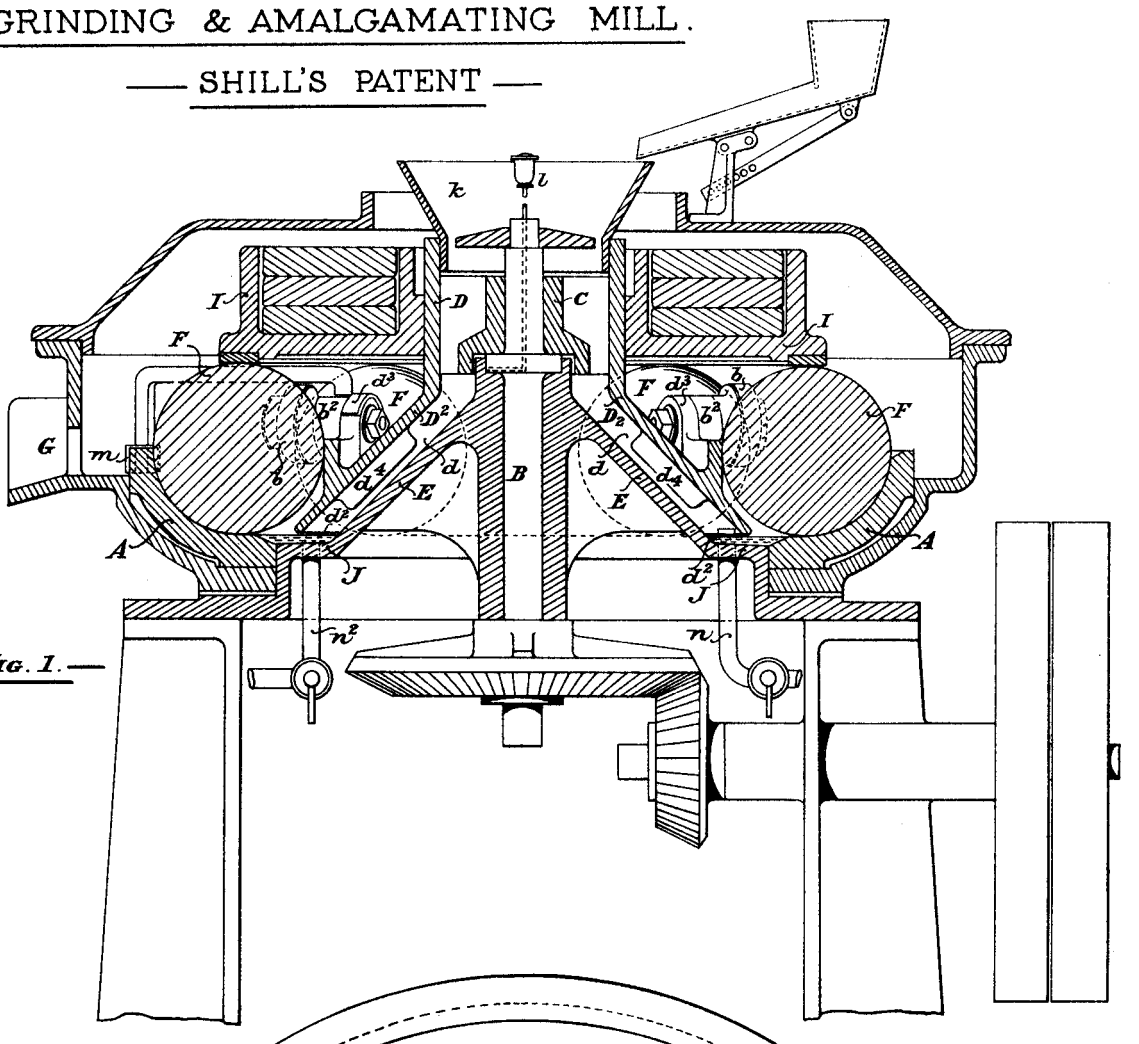
Meanwhile water is supplied from tank A^3, which is kept partially filled, so as to maintain a constant head or pressure, and descends through the pipe A^4 to the two branches in the frame B, where the cocks B^1 and B^2 are situated. These said cocks are operated at the handles B^3 and B^4 to supply the necessary quantity of jet-water into their respective tubes—that is to say, that B^2, to


S
SUPPLY
HOPPER
AUSTIN'S PATENT AMALGAMATOR
Size–21" x 20" in clear.
FLANGE FOR COLUMN
A
60" to top of Column
CHIMNEY
H
C
DISCHARGE
17"
3"
FLUE
C
3"
LEVEL OF QUICKSILVER
LEVEL OF QUICKSILVER
D
1½"
1½"
TUBE 1
TUBE 2
TUBE 3
3
4
5
B
6
7
8
9
TUBE 8
E
18"
TAP
I
F
FIRE BOX

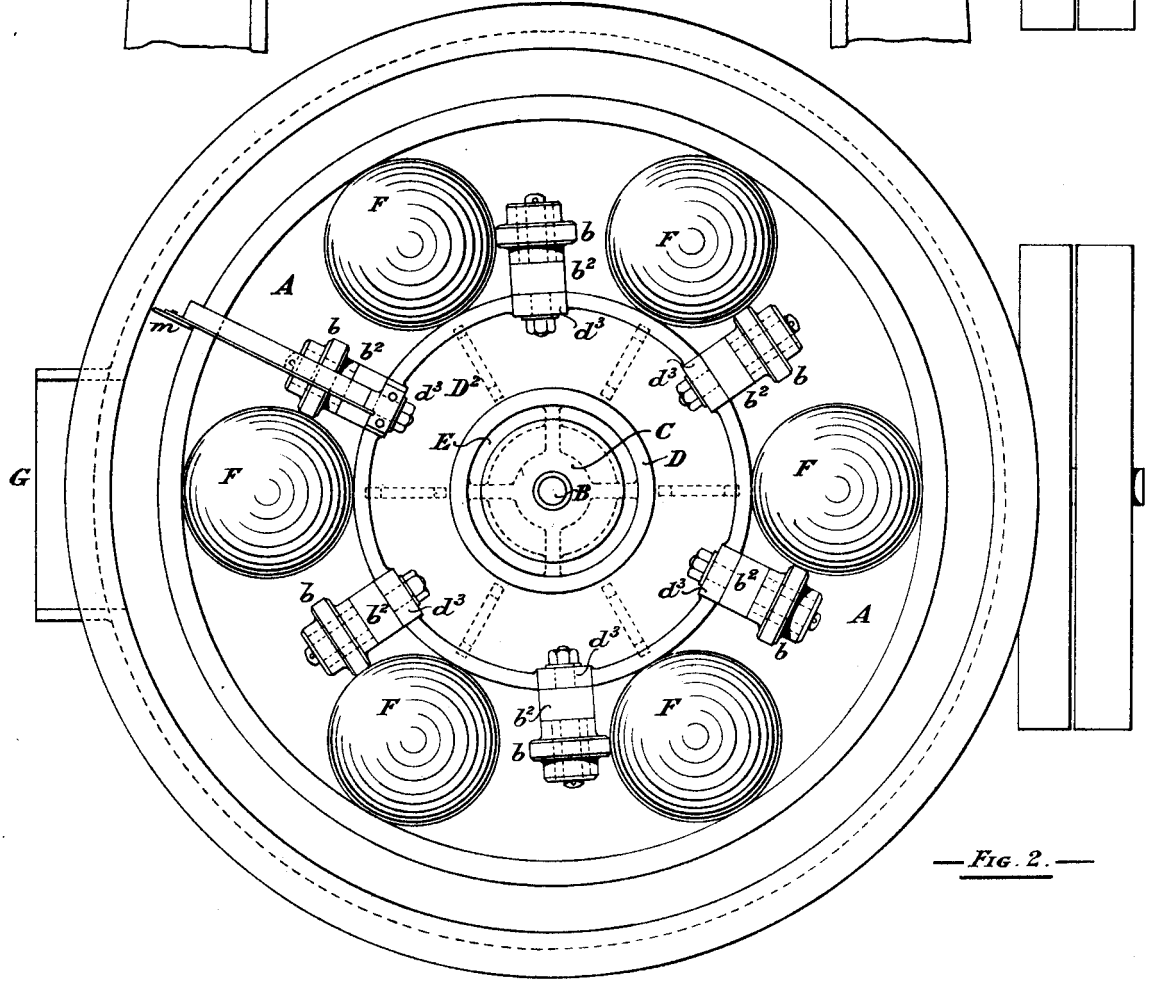
IMPROVED

GRINDING & AMALGAMATING MILL.

— SHILL'S PATENT —



— FIG. 1. —

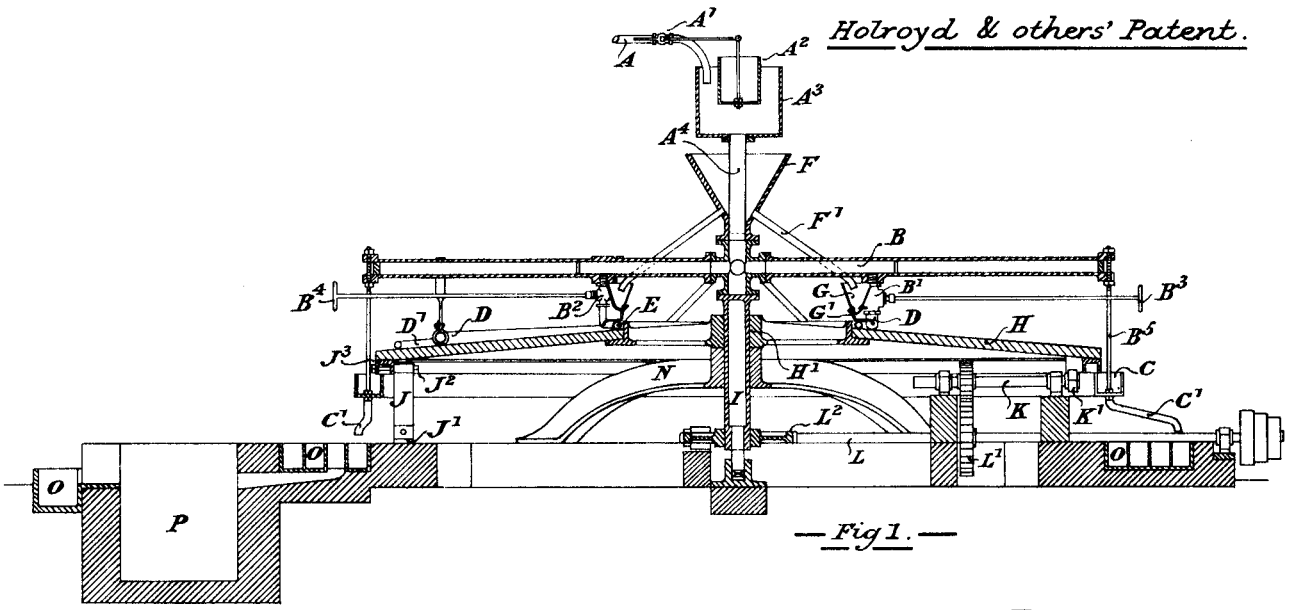


— FIG. 2. —

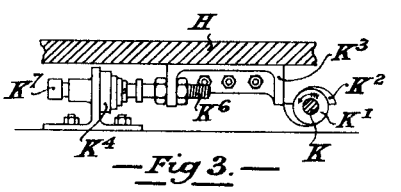
C.H.P. del.

IMPROVED CONCENTRATOR & CLASSIFIER

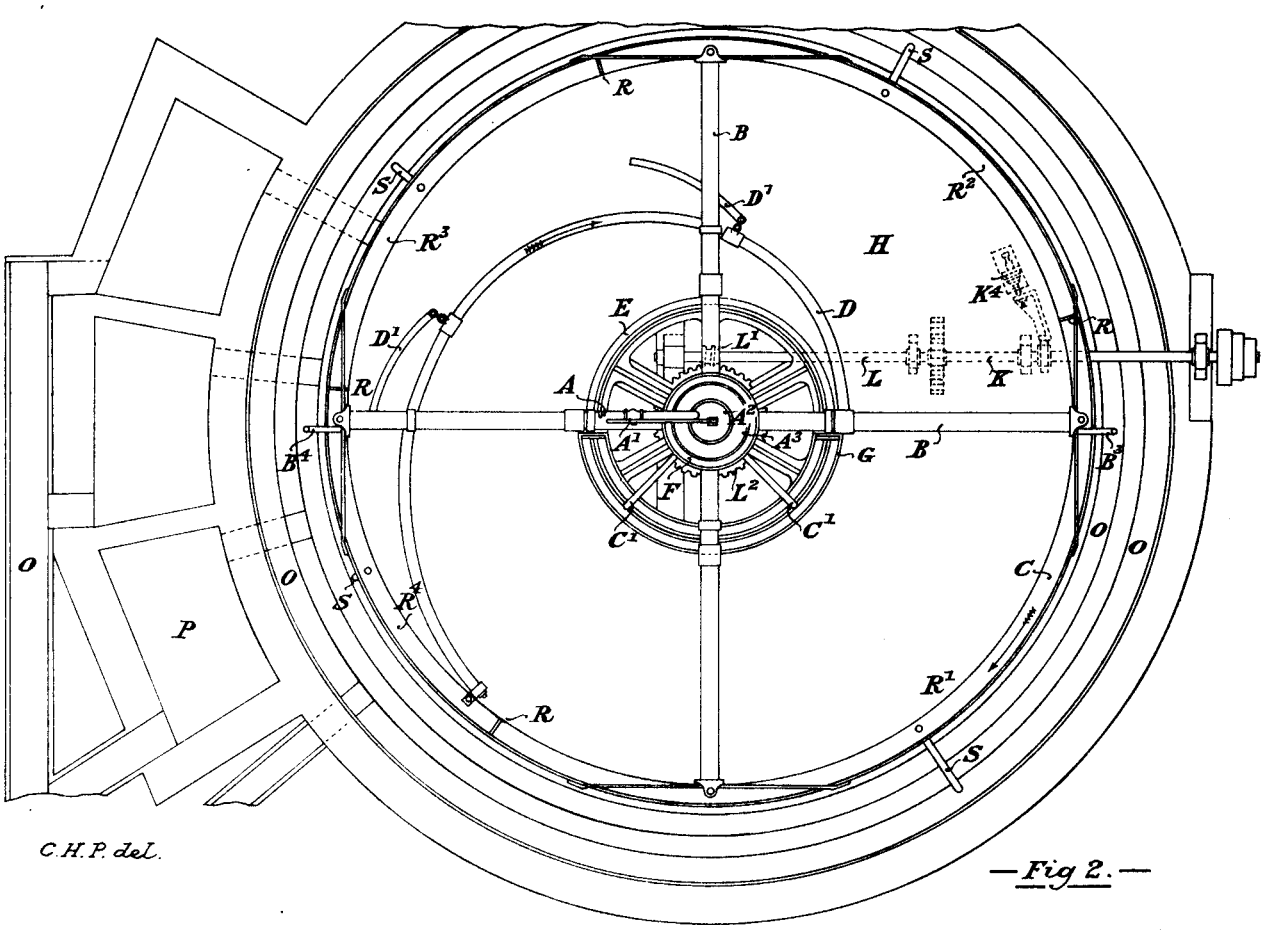
Holroyd & others' Patent.



—Fig 1.—



—Fig 3.—



C.H.P. del.

—Fig 2.—

IMPROVED AMALGAMATOR & CONCENTRATOR

CHANNON'S PATENT

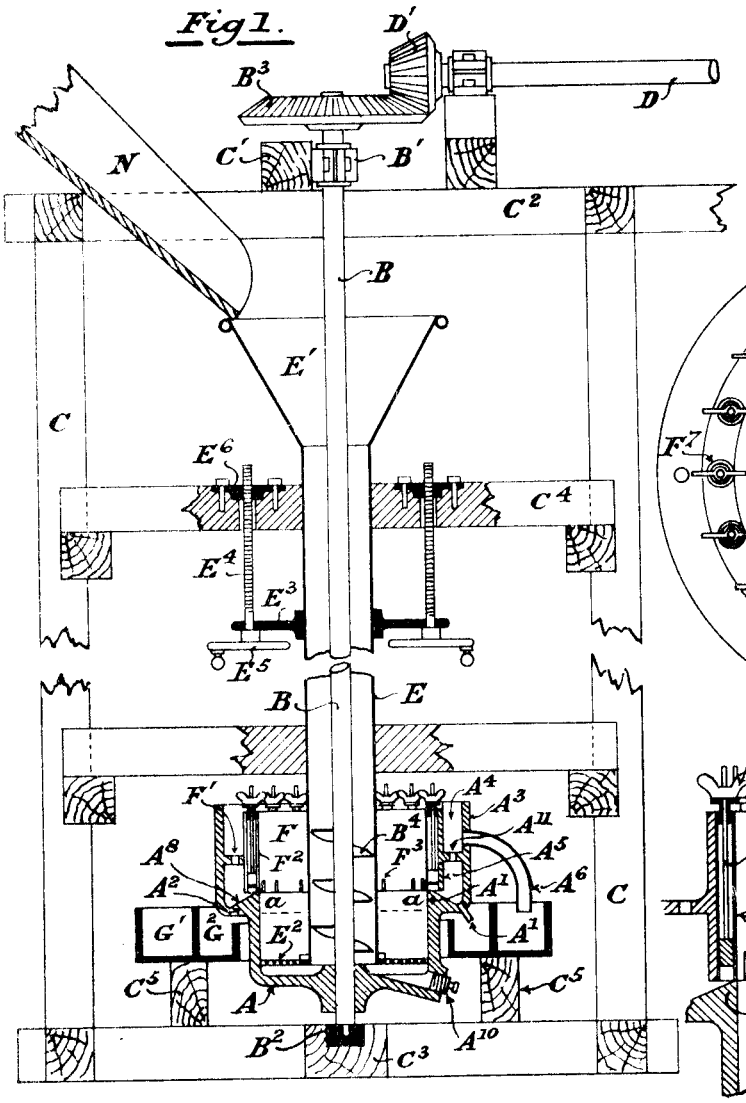


Fig 1.

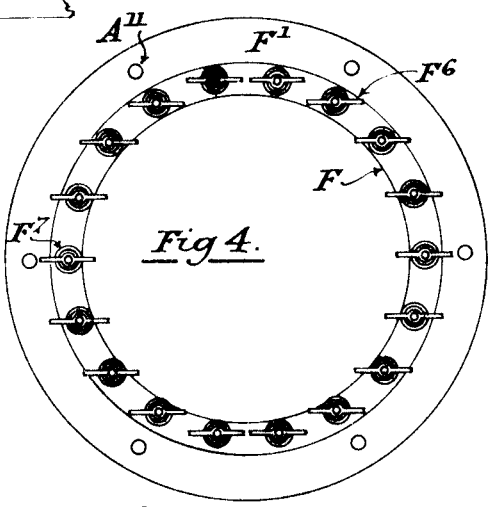


Fig 4.

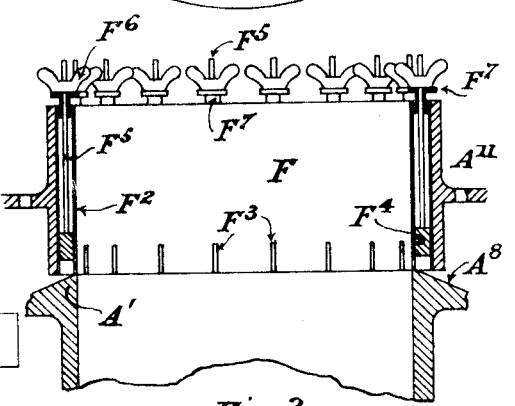


Fig 3.

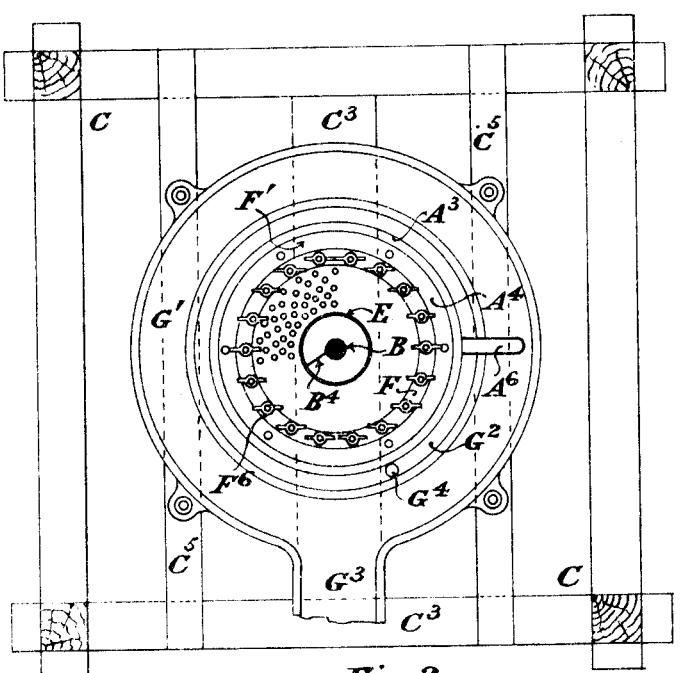


Fig 2.

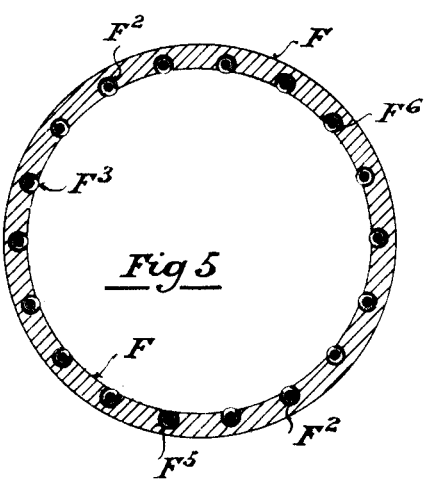


Fig 5

supply the annular perforated tube E, from whence the water squirts or sprays along the surface of the table H, tending to carry down with it the material or ore-pulp flowing from the annular plate G^1, whilst the cock B^1, on being opened, permits a flow of water to supply the curved tube D and its branches D^1. This tube D, as aforesaid, rotates in the direction shown by arrows, and the water squirts or sprays from the perforations in the tube in the direction towards the periphery of the table H, and thus evenly washes away the already concentrated material towards the several divisions of the receiving-trough C, and, by reason of the specific gravity of the particles washed away the lightest portions first and the heaviest portions last, for the purpose of receiving the different grades or portions of different specific gravities, divisions R are provided in the annular receiving-trough C—that is to say, the lightest and valueless gangue, escaping or washing into the section between R and R, and marked R^1, the next and slightly heavier material flowing into R^2, and valuable material into the section R^3, and the most valuable and heaviest into the section R^4 at the end of the bent pipe D. Each of the sections R has a lead-away pipe S to conduct the separated materials to their respective canals, as O, or tanks, as P.

The auxiliary jointed pipes D^1 are radially adjusted by the operator to form division lines for the sections R^2, R^3, and R^4, and to further assist the action of the large tube D.

Having now particularly described and ascertained the nature of our said invention, and in what manner the same is to be performed, we declare that what we claim is,—

1. In concentrators and classifiers: The combination with a circular outwardly descending table, as H, mounted upon flexible plates, as J, and provided with percussive oscillatory motion, as K to K^7, of a curved rotating perforated pipe, as D, substantially as and for the purposes set forth.

2. In concentrators and classifiers: An annular hopper, as F, provided with lead-away feed-ducts, as F^1, and placed around a water-supply pipe, as A^4, in combination with a circular percussive oscillating table, as H, over which a bent water-tube, as D, revolves, substantially as and for the purposes set forth.

3. In concentrators and classifiers: A frame, as B, acting as a duct for water, and at the same time for supporting a circular receiving-trough, as C, and feed-trough, as G, substantially as and for the purposes set forth.

4. In concentrators and classifiers: The combination with a revolving hollow frame, as B, in which a cock, as B^1, is mounted, of a bent tube, as D, substantially as and for the purposes set forth.

5. In concentrators and classifiers: The combination with a revolving hollow frame, as B, in which a cock, as B^2, is mounted, of an annular perforated water-pipe, as E, and outwardly descending circular percussive oscillating table, as H, substantially as and for the purposes set forth.

6. In concentrators and classifiers: The combination of horizontal worm-gear, as L^1 and L^2, placed at the bottom of and revolving a vertical shaft, as I, and at the same time imparting motion to a cam-shaft, as K, with a frame, as B, substantially as and for the purposes set forth.

7. In concentrators and classifiers: Standard, as N, forming a vertical bearing or eyelet for a shaft, as I, on which is mounted a frame, as B, and forming a horizontal central support for a percussive oscillating table, as H, substantially as and for the purposes set forth.

8. In concentrators and classifiers: The combination with a top-feed water-tank, as A^3, in which is set a float appliance, as A^1 and A^2, for regulating the supply of water to such tank, and terminating in a downward pipe, as A^4, of a frame, as B, and bent perforated tube, as D, substantially as and for the purposes set forth.

9. In cencentrators and classifiers: The combination of a frame, as B, curved perforated tube, as D, table, as H, and lead-away canals, as O, substantially as and for the purposes set forth.

10. In concentrators and classifiers: The general mechanical construction, arrangement, and combination of the whole of the parts illustrated on Figs. 1, 2, and 3 of the drawings to form a complete concentrator and classifier.

Dated this 4th day of January, 1894.

A. C. Holroyd. J. G. Pirrie.
E. Hughes. E. J. Rigby.

An Improved Concentrator, usable preferably as an Amalgamator and Concentrator.

I, James Channon, of Beaconsfield, Concord, near Sydney, in the Colony of New South Wales, merchant, do hereby declare the nature of my invention for "An Improved Concentrator, usable preferably as an Amalgamator and Concentrator," and in what manner the same is to be performed, to be particularly described and ascertained in the following statement:—

This invention relates to an improved concentrator for the treatment of material such as crushings or tailings from stamper batteries or other reducing mills, or any other finely-divided metalliferous material for the separation of the heavier minerals and particles, such as pyrites and the like, contained therein from gangue.

This improved concentrator, usable preferably as a combined amalgamator and concentrator, onsists of certain improvements in, and additions to, a rotary amalgamator, in respect of which New Zealand letters patent were granted to me on the 6th day of January 1893, No. 5977, in which a cylinder or pan containing mercury is revolved about a stationary perforated disc, having a central feed-pipe. Now, with such revolving cylinder or pan, I combine and arrange an outer annular receiving-space or vessel, hereinafter called "the concentrates receiver," having communication with the said cylinder or pan through slots, orifices, holes, or apertures, whose extent of opening is under regulation or adjustment. From the said concentrates receiver discharging-spouts are arranged over an annular trough or launder, from which the contents may be withdrawn when required. Other discharging-spouts are led from above a division or false bottom plate in the concentrates receiver and overhang a second annular trough or launder for the gangue or waste, with an offset directing said gangue or waste to where required.

But in order that I may be clearly understood, reference will now be made to the drawings herewith, in which Fig. 1 is a sectional elevation and Fig. 2 a sectional plan of a concentrating machine or combined amalgamating and concentrating machine constructed according to this invention; while Figs. 3, 4, and 5 are sectional elevation plan and sectional plan respectively on a larger scale of the device for regulating the openings to the concentrates receiver.

The cylinder or pan A is keyed upon the vertical spindle B, set in bearing B^1 on cross-piece C^1 from top frame C^2 of framing C, and in footstep bearing B^2 on bottom frame C^3, and is revolved by the gearing of toothed bevel wheel B^3 with toothed bevel pinion D^1 on spindle D, driven by belt or other gearing from any suitable motor engine. Affixed to this spindle B near its bottom end is a spiral or worm B^4 within a pipe or casing E, having at its upper end a funnel-mouth or hopper E^1, and secured to its lower end is a perforated disc or plate E^2 near to the bottom of pan A. Around the pipe or casing E are clamped the plates or wings E^3, through which pass the male screws E^4, on whose bottom ends are hand-wheels E^5 taking under said plates or wings said male screws E^4, passing through female screws or nuts E^6 bolted to cross-pieces C^4 of the framing C, so that by turning the hand-wheels E^5 and screwing the male screws E^4 up or down in nuts E^6 the pipe or casing E is raised and lowered, and the distance between plate E^2 and the bottom of the pan A adjusted as desired.

The pan A is enlarged at its upper end by means of a vertical periphery A^3 and horizontal annular flange-piece A^2. On the top edge A^1 of the cylinder or pan proper is set a ring or cylinder F, whose inner periphery rises from said edge A^1 flush with the inner periphery of the pan, so as to form the annular concentrates receiver between it and the periphery A^3. The ring or cylinder F has a flange F^1 fitting within the periphery A^3 to form a false bottom in the concentrates receiver, dividing it into compartments or chambers A^4 and A^5, having communication through one or more plug-holes A^{11}. From these compartments spouts or pipes A^6 and A^7 lead to troughs or launders G^1 and G^2 respectively, said troughs being formed concentric and supported by cross-pieces C^5 of the framing, the former having discharge-orifice G^3, and the latter an offset, or discharge-shoot, or way, marked G^4. In the bottom edge or face of the ring or cylinder F are numbers of holes, apertures, or recesses, equidistant apart, into which are inserted pieces of pipe or tubing F^2 having one or more saw-cuts or slots F^3 at different points in the periphery, having a vertical length of, say, 1in. or more, which said cuts or slots, if more than one, are cut in each piece of pipe, and may be made of different widths or gauge. Each of these pipes F^2 are inserted in an aperture in the ring, that one of these slots will form communication between the interior of the ring and the interior of the tube, whose bottom end is open to the compartment or chamber A^5 above the inclined botttom A^8, thus forming a way from the pan A to the chamber A^5. In each of the pipes or tubes F^2 is a piston F^4 having a rod or stem F^5 passing upward through the ring F, and screwed at the top end to take a thumb-screw F^6 above a gland F^7, the screwing up or down of which thumb-screw will raise or lower the piston F^4 within the pipe F^2, and regulate the passage from the interior of ring F to the chamber A^5. Instead of one set of tubes or pipes F^2, having a number of slots or saw-cuts of different gauge or width therein, there may be two or more sets, each set having a recognised gauge, one set being withdrawn from ring F and another inserted when desirable, and as may be needful to adjust the discharge-apertures to suit the percentage quantity of concentrates in the material under treatment.

In use as a concentrator alone, the pan is filled with suitable heavy material, say mercury, and is revolved. The material or pulp to be treated is fed with water to the hopper E^1 by shoot H, and fills pipe or casing E to the desired pressure-level, and, being assisted by the worm or spiral B^4, is forced out of pipe E to the bottom of the pan A, where the centrifugal force communicated by said pan to its contents distributes the material under the perforated disc or plate E^2, and where it, finding the holes therein, rises to the surface through the mercury or other suitable heavy material or medium, the lighter particles being discharged over the top of ring F into chamber or trough A^4, whilst the heavier or coarser particles, in passing upward with the water and sand, are thrown outwards against the periphery of the pan, and, finding the saw-cuts or slits F^3 in the pipes or tubes F^2 (which are regulated, as hereinbefore described, to suit the kind of material treated), pass through said pipes to the chamber A^5 down the inclined face A^8. Other fine heavy particles which may have been carried upwardly and discharged with the lighter gangue over the top of ring F into chamber A^4 and settle upon its false bottom F^1, from which at intervals they are discharged by removing plugs in holes A^{11} into the compartment A^5, while the light gangue flows over rim A^3 into trough G^1, and is carried to waste. The concentrates are discharged from the receiver A^6 through spouts or pipes A^7 into trough G^2, and from thence are discharged into a convenient storage-tank or other receptacle through orifice G^4.

In use as a combined amalgamator and concentrator, which is the preferable use, the heavy material or medium placed in the pan A must be mercury, and sufficient of it, say, to fill it and the central feed-pipe up to level of dotted line *aa*, Fig. 1. The operation of amalgamation is carried on in the same manner as described in the specification of my previous patent, hereinbefore referred to, while, in addition, the concentration of the heavier particles takes place as hereinbefore explained.

Having now particularly described and ascertained the nature of my said invention, and in what manner the same is to be performed, I declare that what I claim is,—

1. An improved concentrator, usable preferably as an amalgamator and concentrator, the essential features of which are a revolving plan, a stationary perforated disc at the bottom end of a central feed-pipe, an outer annular concentrates receiver, communicating holes or orifices between said pan and said concentrates receiver, discharging-spouts from the top of said pan and from said concentrates receiver, and troughs or launders for the respective discharges, substantially as herein described and explained.

2. In a concentrator of the class set forth, the combination and arrangement with a pan, such as A, on a vertical revolving spindle, such as B, and disc or plate, such as E^2, on feed-pipe, such as E,

of enlarged peripheral rim, such as A^3, and bottom or flange piece, such as A^2, and ring or cylinder, such as F, together forming annular concentrates receiver, such as A^4 and A^5, having communication by holes or apertures, preferably adjustable as to size with the said pan, such as A, substantially as herein described and as illustrated in the drawings.

3. In a concentrator of the class set forth, the combination and arrangement with a revolving pan, such as A, having an annular concentrates receiver, such as A^4 and A^5, of ring or cylinder, such as F, having holes or apertures for pipes or tubes, such as F^2, having slits or cuts, such as F^3, piston, such as F^4, and devices for moving such pistons, such as F^4, so as to adjust the length of said slits or cuts, such as F^3, say, such as rods F^5 and thumb-screws F^6, substantially as herein described and explained and as illustrated in the drawings.

4. In a concentrator of the class set forth, the combination and arrangement with a revolving pan, such as A, having an annular concentrates receiver, such as A^4 and A^5, of false bottom, such as F^1, discharge-spouts or -pipes, such as A^6 and A^7, and troughs or launders, such as G^1 and G^3, substantially as herein described and explained and as illustrated in the drawings.

5. The particular combination and arrangement of mechanical parts, altogether forming an improved concentrator, usable preferably as an amalgamator and concentrator, substantially as herein described and explained, and as illustrated in the drawings.

Dated this 8th day of August, 1893. JAMES CHANNON.

IMPROVEMENTS IN THE CHLORINATION OF PULVERISED ORES CONTAINING GOLD OR SILVER AND IN APPARATUS THEREFOR.

I, Joseph William Sutton, of Eagle Street, Brisbane, in the Colony of Queensland, engineer, do hereby declare the nature of my invention for the "Improvements in the Chlorination of Pulverised Ores containing Gold or Silver and in Apparatus therefor," and in what manner the same is to be performed, to be particularly described in and by the following statement:—

My invention relates to the chlorination of pulverised ores containing gold and silver in revolving barrels, cylinders, or other vessels.

Hitherto the material, when being chlorinated, has not been sufficiently disintegrated so as to allow the chlorine to attack every particle of the ore, as the ore, being in a semi-liquid or mortar-like state, was turned over in the barrel or vessel in masses or lumps.

One part of my invention consists in chlorinating the ore while in a semi-dry state in a revolving-barrel or other vessel. By the term "semi-dry" I mean ore containing about 5 to 15 per cent. of moisture.

In carrying out this part of my invention I place the dry ore in the barrel or other vessel, and moisten it, until a handful, when pressed together, will not, when released, form an adhesive mass, but will crumble and fall away at a slight touch; or I may make the ore semi-dry before placing it in the barrel. Chlorine is then introduced and the barrel revolved. As the semi-dry ore has no tendency to fall over in masses or lumps while the barrel is being rotated (at about fifteen revolutions per minute) the chlorine is enabled to attack each particle. When the material has been sufficiently chlorinated it is discharged for further treatment for the recovery of the gold or silver.

Another part of my invention consists essentially in chlorinating ores, containing gold or silver, either while in a semi-dry or semi-liquid state, in a revolving-barrel or vessel provided internally with a screen, so that the material being chlorinated is screened at each revolution.

The forms of screens and barrel may be of various shapes; but I prefer to carry out the operation in the apparatus shown in the accompanying drawings, in which Fig. 1 is a front elevation of my apparatus, Fig. 2 is a sectional plan, Fig. 3 is a longitudinal section, while Fig. 4 is a cross section at AB, Fig. 1. The same reference letters indicate like parts throughout the figures.

C Cl are fast and loose pulleys; D Dl, gear wheels; E El, bearings; F, chlorinating vessel, provided with a lead or other chlorine-resisting lining; G is screen comprised of a number of bars coated with lead, and having an oval section as shown at Fig. 3; H are plates securing the ends of bars of screens by means of bolts; J K is charging-hole provided with a cover, Kl; M is chlorine inlet; and Ml, steam inlet pike for keeping the passage M2 clear of any particles of ore; M3, bracket supporting the chlorine and steam-pipes.

The operation is carried out as follows:—

The vessel F is revolved until the charging-hole K is at its highest point, when it is charged, preferably with semi-dry ore (which may be roasted, if necessary), until it is one-half full. The cover Kl is then screwed down, and chlorine introduced through pipe M and passage M2. The vessel is then rotated at about fifteen revolutions per minute, so that at each revolution the whole of the material within the vessel is screened twice through the bars of screen G. When the ore has been sufficiently chlorinated, the vessel F is rotated until the charging-hole K is at its lowest point, when cover Kl is unscrewed and the contents discharged, to be further treated for the recovery of the gold or silver.

When it is desired to carry out the operation continuously I make the chlorinating vessel of an approximately cylindrical or rectangular shape, and of a length of about ten times its diameter. The vessel is supported in suitable bearings, and inclined at a slight angle to the horizontal, so that ore charged in at the higher end will pass through the screen at each revolution, and gradually work down to the lower end. In order to insure that no particles of the ore should reach the discharge-end too quickly, I prefer to provide the vessel with webs extending from the internal periphery of the vessel to within a short distance of the screen. The ore is regularly fed into the vessel (preferably by an automatic feeder, such as is well known), and when about half-full the chlorinated ore is discharged through an opening at the lower end at each revolution of the vessel. The chlorine may be introduced into the vessel through one of the trunnions, as shown in Figs. 2 and 3.

Having now particularly described and ascertained the nature of my said nvention, and in what manner the same is to be performed, I declare that what I claim is,—

1. In the chlorination of pulverised ores, containing gold or silver, chlorinating the ore when in a semi-dry state in a revolving barrel or vessel, substantially as hereinbefore described and explained.

2. In the chlorination of pulverised ores, containing gold or silver, in a revolving barrel or vessel screening the whole of the ore at each revolution, substantially as hereinbefore described and explained.

3. In apparatus for chlorinating pulverised ore, containing gold or silver, the combination with a barrel or vessel capable of being revolved, such as F, of a screen, such as G, substantially as hereinbefore described and illustrated in the drawings.

4. In apparatus for chlorinating pulverised ores, containing gold or silver, the use of a vessel (capable of being revolved) inclined at a slight angle to the horizontal, and provided with a screen, and with or without webs, substantially as hereinbefore described and explained.

Dated at Brisbane, in the Colony of Queensland, this 10th day of July, 1893.

J. H. Sutton.

Improvements in the Extraction of Gold and Silver from Ores.

I, Carl Maria Pielsticker, of No. 43, Connaught Road, Harlesden, in the County of Middlesex, England, engineer, do hereby declare the nature of my invention for improvements in the extraction of gold and silver from ores, and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

My invention has for its object the extraction of gold and silver particularly from sulphide, and from such ores in which the precious metals exist in a state of extremely fine division, and it consists essentially in treating the powdered ore with a solution of cyanide of potassium or a cyanide or cyanogen, yielding substance in conjunction with an electric current, continuous circulation of the solvent, continuous precipitation of the dissolved precious metals by electrolysis, and continuous regeneration of the solvent.

In carrying out my invention, I employ a tank, marked A on the accompanying drawing, which I call the ore-tank, in which the ore is subjected to the treatment with cyanide of potassium in conjunction with an electric current. About 3in. from the bottom I place a perforated plate H, preferably of iron or carbon, covered with a porous material, such as cocoanut matting. The plate H serves as anode, and is insoluble, or practically so, in cyanide of potassium.

If made of iron, I prefer a highly carburetted iron, or ore containing a high percentage of silicum. Near the top of the ore-tank I place a second perforated plate G, which serves as cathode. Both these plates are connected by means of insulated wires e-e^1 with a dynamo D or other source of electricity.

The ore-tank A is connected near its top by means of a pipe with a second tank B, containing a number of baffle plates K, or their equivalent, which are destined to arrest any suspended matter flowing over with the solution from the ore-tank, and which otherwise would greatly interfere with the precipitation of the dissolved precious metals, in the following tank C connected with the tank B near the top by means of a pipe. The precipitating-tank C contains one or more pairs of electrodes M and N, connected with the dynamo D, or other source of electricity, by means of the insulated wires g and g^1, of which the anode preferably consists of carbon or other material, insoluble, or practically so, in cyanide of potassium. A pump P is connected with the ore-tank A under the anode H on the one hand, and with the top of the depositing-tank C on the other hand, enabling me to maintain a circulation of the solvent through the set of tanks.

In operating my invention, I fill the ore-tank A between the electrodes H and G with powdered ore, and admit into the three tanks A, B, and C a solution of cyanide of potassium, filling them above the level of the pipes which connect one tank with the other. The strength of the cyanide solution may vary, care being taken to have sufficient cyanogen present to bring the gold and silver in the ore into the solution, the amount of which has previously been ascertained by assay. I connect the electrodes H and G in the ore-tank A, and M and N in the depositing-tank C, with the dynamo D, or other source of electricity, and force the cyanide solution from below through the ore in the tank A.

The solution, pregnant with dissolved precious metals, overflows into the settling-tank B, where it clears itself from suspended matter, and becomes thus fit to part with the dissolved precious metals on overflowing into the depositing-tank C, where the latter are precipitated on the cathode, and from which they are recovered by amalgamation or otherwise. The cyanide solution, freed from dissolved metals, and therefore in a better condition to dissolve more metal than when loaded with metal in solution, is pumped from the depositing-tank C, again through the ore in the tank A, where it dissolves a fresh proportion of precious metals, and, so on, continuously, until the precious metals contained in the ore under treatment are dissolved.

In this manner my process becomes a continuous one, of dissolving the precious metals from the ore, preparing the solution pregnant with dissolved metals for electrolysis by separating continuously the suspended matter therefrom, precipitating continuously the dissolved metals by electrolysis, and regenerating continuously the solvent for further action on the undissolved precious metals still contained in the ore. Very little of the precious metals are precipitated on the cathode G in the ore-tank, as the amount of the suspended matter present in the solution interferes with precipitation in this tank.

The electric current in the depositing-tank must be of low tension, and so regulated as to be of just sufficient strength to deposit the gold and silver without also decomposing the cyanide of potassium; the gold and silver, being more readily precipitated from their double salts of cyanide of gold (or

IMPROVED CHLORINATING PLANT

SUTTON'S PATENT

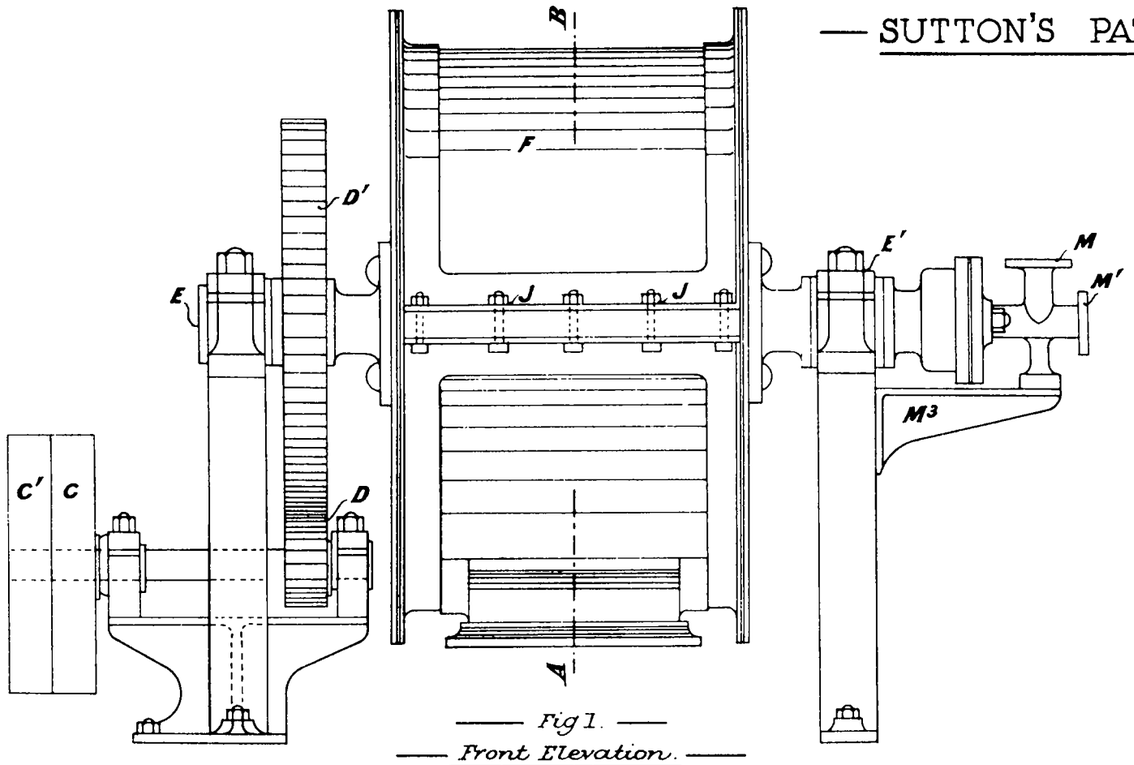


Fig 1.
Front Elevation.

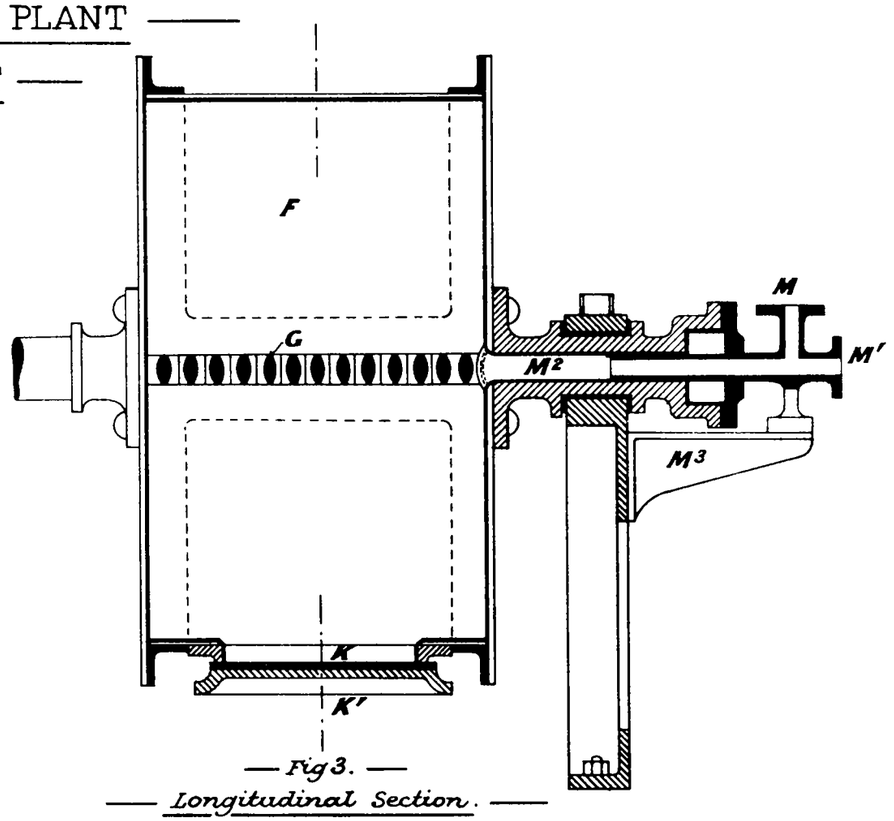


Fig 3.
Longitudinal Section.

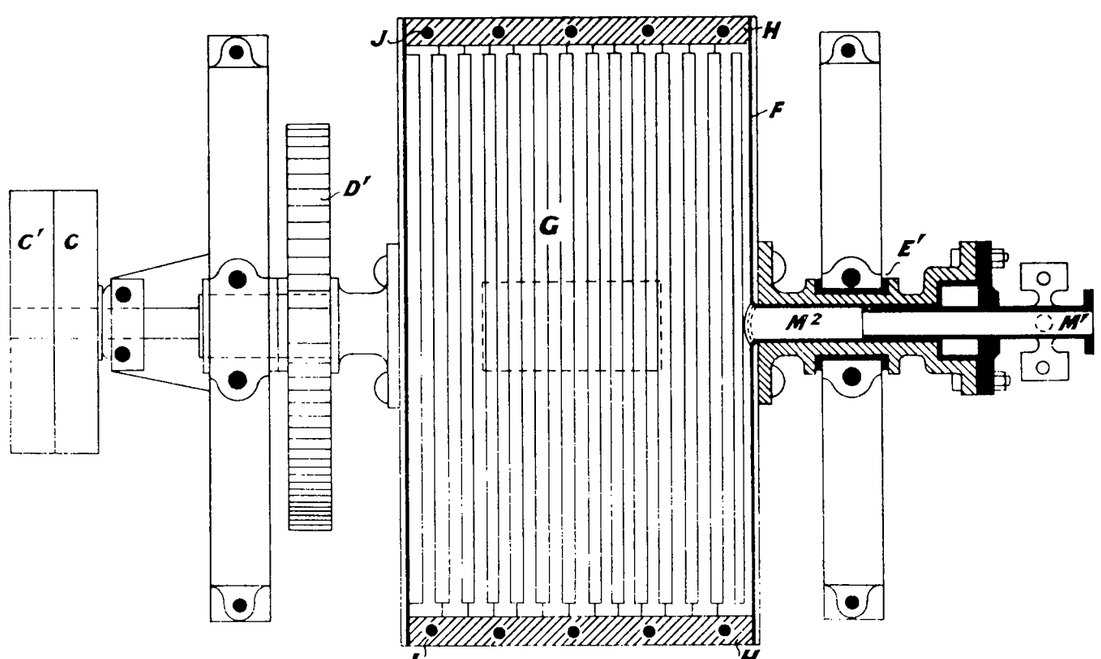


Fig 2. Sectional Plan.

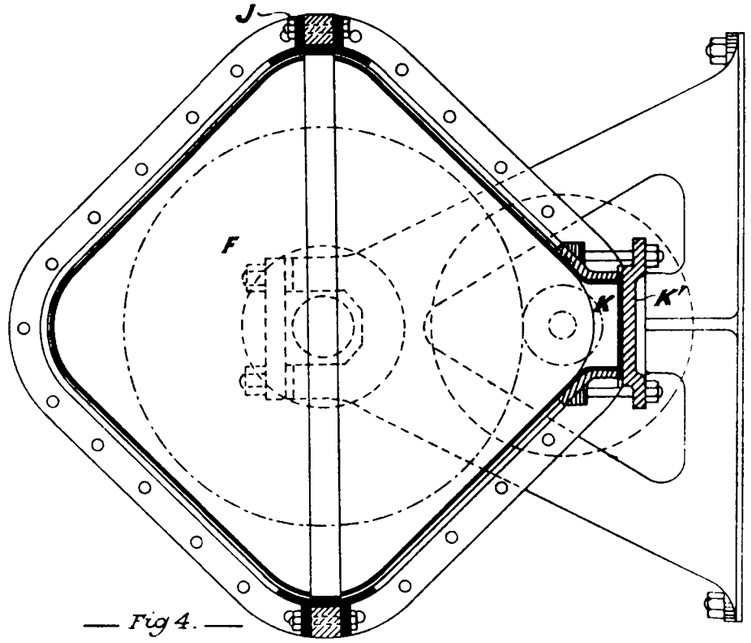
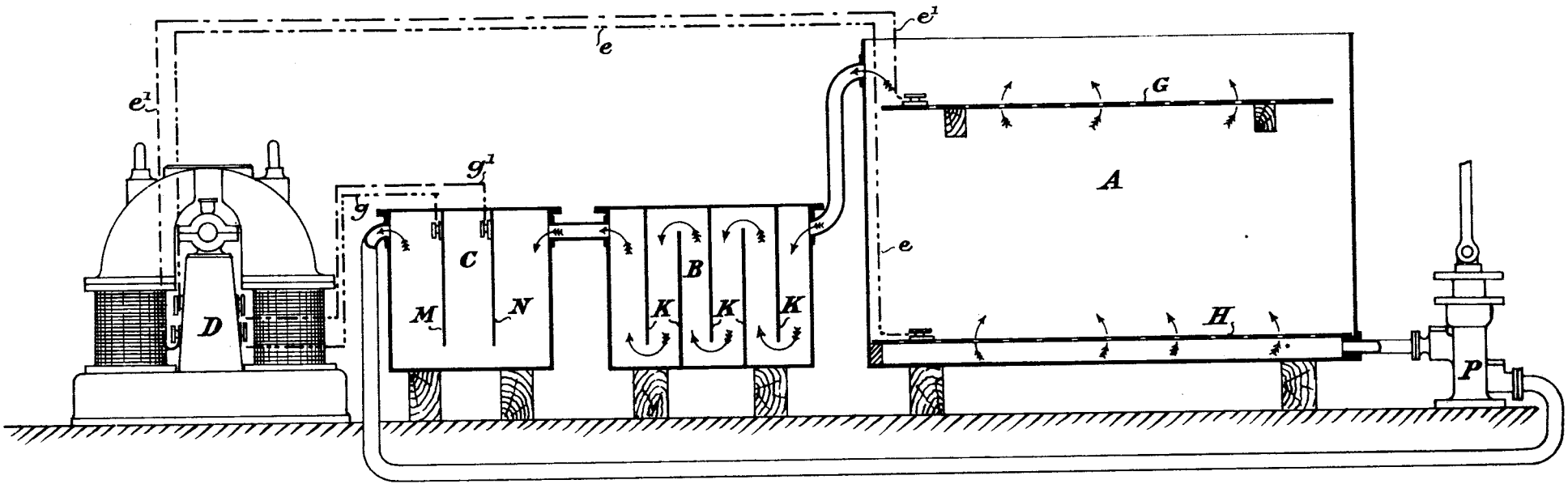


Fig 4.
Cross Section on line A.B.

IMPROVED APPARATUS FOR THE EXTRACTION OF GOLD & SILVER FROM ORES.

— *C. M Pielsticker's Patent.* —



silver) and potassium than the cyanogen, is set free from the simple salt of cyanide of potassium so long as the current of electricity is sufficiently low in tension, and so long as there are metals present in the solution. The original solution can therefore be used over and over again for a long time, and only the loss made good occasionally.

In practice, I find that an electro-motive force of about one volt, and an intensity of about ten amperes per square metre of surface of cathode, is well adapted for depositing the gold and silver in the tank C. I may find it desirable to employ a current of electricity of greater potential in the ore-tank A and of lesser potential in the depositing-tank C.

The great advantage in treating ores with cyanide of potassium in conjunction with an electric current lies in the fact that the precious metals are attacked by the cyanide solution more energetically in conjunction with a current of electricity than without one; further, when the dissolved precious metals are precipitated by means of an electrical current and an insoluble anode very little cyanide and no metal is consumed, as is the case when, for instance, zinc is used as a precipitant, when not only zinc is consumed, but also cyanide of potassium in the formation of a double salt of cyanide of zinc and potassium. Moreover, serious losses in gold and silver are occasioned in the recovery of the precious metals from the zinc slimes, whereas nothing can be simpler than their recovery from the cathode by amalgamation. Again, the precipitation of gold and silver is greatly accelerated by the electric current.

When these metals are precipitated by zinc without a current of electricity the latter goes into solution as a double salt of cyanide of zinc and potassium, but the amount of zinc which is converted into cyanide of zinc is directly proportionate to the time during which it is in contact with the cyanide solution. Therefore, the more time is consumed in precipitating the gold and silver, the more cyanide and the more zinc will be wasted.

The cyanide process is most advantageously employed on ores in which either the gold is so finely divided in a free state that it is difficult to retain it by older methods, or for sulphide ores. Free gold is certainly more quickly dissolved by cyanide of potassium in conjunction with an electrical current than without one. As regards pyritic ores, if they are simply iron-pyrites, as they are in a great number of cases, a cyanide of potassium solution, whatever its strength may be, has as little action on them when used in conjunction with an electric current of the strength I use as without one, only the gold and silver in the ore are more quickly dissolved in conjunction with an electrical current than without one.

If the ores contain sulphides, oxides, or carbonates, for instance, of copper and zinc, these are as easily dissolved by a cyanide of potassium solution whether employed by itself or in conjunction with an electric current such as I use. Such ores, however, I prefer to treat first with, say, a 5-per-cent. sulphuric acid or other acid solution in water, or a strong solution of sulphurous acid in water in sufficient quantity to dissolve such metals, then leach with water, and then treat with the cyanide solution in conjunction with the electric current.

I would have it understood that I do not limit myself to the precise details herein set forth and illustrated on the drawing—for example, the number, nature, and position of electrodes, of the sources of electricity, and of the number, shape, and position of the tanks; all may be varied while retaining the construction and combinations for the proper carrying-out of my process of extraction of gold and silver from their ores; further, I am aware that cyanide of potassium has been used in conjunction with an electric current for like purposes, and I make no broad claim thereto.

Having now particularly described and ascertained the nature of my said invention, and the manner in which the same is to be performed, I declare that what I claim is,—

1. The process of separating gold and silver from their ores which consists in treating the powdered ore with a solution of cyanide of potassium in conjunction with an electric current, depositing the precious metals constantly by means of a current of electricity of low tension and electrodes, of which the positive one is insoluble in cyanide of potassium, and bringing the cyanide of potassium solution thus freed from dissolved metals constantly again into contact with the ore, whereby I obtain a continuous process of extraction and precipitation, all substantially as herein described.

2. In the process of separating gold and silver from their ores by means of a solution of cyanide of potassium in conjunction with an electric current, bringing the cyanide of potassium solution freed from dissolved metals continuously into contact with the ore, substantially as described.

3. In the above-described process of separating gold and silver from ores by means of a solution of cyanide of potassium in conjunction with an electric current, depositing the dissolved metals by means of electrodes contained in depositing-tank or tanks, an electric current being passed through the ore-tank and depositing-tank, subtantially as set forth.

4. In the above-described process of separating gold and silver from their ores by means of a solution of cyanide of potassium in conjunction with an electric current, treating the ore with an acid in combination with a subsequent treatment of cyanide of potassium in conjunction with an electric current and continuous circulation of the solution, substantially as described.

5. In the above-described process of separating gold and silver from their ores by means of a solution of cyanide of potassium in conjunction with an electric current, subjecting the ore and solution in the ore-tank to an electric current of greater potential, and depositing the dissolved metal in a depositing-tank by an electric current of lesser potential, substantially as described.

6. In the above-described process of separating gold and silver from their ores in conjunction with an electric current, the use of a current of electricity of sufficient strength to decompose the double salt of cyanide of gold or silver and potassium without decomposing the cyanide of potassium itself.

7. In the above-described process of separating the gold and silver from their ores in conjunction with an electric current, the combination of an ore-tank with a settling-tank and a depositing-tank, substantially as described.

CARL PIELSTICKER,
By his agent, W. H. QUICK.

Dated this 14th day of December, 1893.

IMPROVEMENTS IN RECOVERING GOLD AND OTHER PRECIOUS METALS FROM THEIR ORES.

I, Carl Moldenhauer, of Frankfort-on-Maine, in the Empire of Germany, do hereby declare that the nature of my invention for improvements in recovering gold and other precious metals from their ores, and the manner in which the same is to be used, are particularly described and ascertained in and by the following statement :—

This invention relates to extracting gold and other precious metals from their ores by means of a solution of cyanide of an alkali or an alkaline earth, and has for its object to render the process more expeditious and considerably cheaper than heretofore.

The invention consists, firstly, in adding to the cyanide solution an artificial oxidizing agent; and, secondly, in precipitating the extracted precious metal out of its cyanide solution by means of aluminium or alloys or amalgam thereof.

As to the first part of my invention, I have found that the dissolving action of the cyanide solution on the precious metal is highly expedited, and much cyanide is saved if an artificial oxidizing agent is added to the said cyanide solution. As such an artificial oxidizing agent, I use, by preference, ferricyanide of potassium or another ferricyanogen salt of an alkali or of an alkaline earth. In either case, the ferricyanogen salt is preferably employed in alkaline solution. The result of this addition of an artificial oxidizing agent is that the dissolving action of the solvent is rendered more energetic, and consequently a considerably smaller quantity of the solvent is required. Thus, by the addition of ferricyanide of potassium or other ferricyanogen salt in alkaline solution, as much as 80 per cent. of the potassium may be saved. The proportions preferred are from one-half to two parts of ferricyanide to one part of cyanide.

It may be remarked that the ferricyanide of potassium alone will not dissolve the gold, and does not, therefore, come under the category of the solvent heretofore employed in processes of extraction. It does not, therefore, render unnecessary the employment of the simple cyanide as a solvent, but only reduces the amount required owing to the capacity of the ferricyanide to act as an oxidising agent, consequently the cyanogen of the ferricyanide is not used to form the gold cyanide compound. I may also employ permanganate of potash as the oxidizing agent instead of the ferricyanide. The said permanganate of potash is also added in solution and in the same proportions as before—namely, from one-half to two parts of permanganate to one part of cyanide.

In lieu of permanganate of potash, any other suitable oxidizing agent can be used in carrying out my invention in practice, the invention not being restricted to the use of any special oxidizing agent, but includes the use of an agent that exerts an oxidizing action in the cyanide solution. The process can be carried out in a ball-mill lined with porcelain, wood, or other substance unattackable by the chemicals employed.

I may also use the cyanide solution and the oxidizing agent in combination, with a preliminary treatment of the ore with any acid or salt that renders the precious metal better adapted to the subsequent treatment of the cyanide solution.

The second part of the process consists in precipitating the dissolved gold or precious metal out of its cyanide solution by means of aluminium, aluminium alloy, or aluminium amalgam; but this can also be applied with advantage to sulphurised solutions containing free alkali—that is to say, solutions which contain gold in the form of sulphuret, or hyposulphide of gold.

Zinc has heretofore been employed in practice by preference in precipitating gold from the cyanide solutions obtained by leaching auriferous ores. The employment of zinc for this purpose is found, however, to be attended with serious disadvantages. Now, I have discovered that aluminium can be employed for this purpose in place of zinc, without the disadvantages attending the use of the latter.

Whilst zinc forms a combination with the bound or free compound of cyanogen and alkali contained in the cyanide solution, aluminium separates the gold very quickly from the cyanogen solution without entering into combination with the cyanogen, but simply reacting with the caustic alkali which is present at the same time. By the action of aluminium the cyanide of potassium employed for leaching the gold out of its ore is regenerated, which is not the case when zinc is employed. But the zinc does not confine itself to entering into combination with the cyanogen of the cyanogen compounds of the gold, but also acts upon the free cyanide of potassium contained in the solution, so that a great part of the latter is consumed; but this is not the case when aluminium is employed.

These results are of the greatest importance when the solution separated from the gold is to be employed in subsequent gold-extracting operations, as the whole of the cyanogen in the regenerated and liberated cyanide of potassium is enabled to renew its action; but the lyes resulting from the employment of zinc cannot be employed with the same advantage in subsequent operations for the extraction of gold. Numerous attempts have been made to regenerate the zinc, but are found to be inconvenient and costly. It is consequently evident that an important saving in cyanide of potassium is obtained by the employment of aluminium.

Aluminium acts in a like manner in a sulphurised alkaline solution—that is to say, in a solution containing the gold in the form of sulphuret of gold or hyposulphide of gold. It does not enter into combination with the sulphur in a solution of this description. This great and important advantage attending to the employment of aluminium, aluminium alloys, or aluminium amalgam, is combined with other advantages, as follow :—

Aluminium is far less subject to oxidization than is zinc, so that it can be sent from its place of production in the form in which it is to be used for the precipitation, whereas when zinc is employed it is considered to be an important advantage to reduce it to the required form at the place where it is employed, and immediately before using it. For the same reason, the repeated employment of the aluminium is admissible for continuous precipitation.

Finally, the quantity of aluminium required for precipitating the same quantity of precious metal is about four times less than the amount of zinc required to produce the same effect.

I am aware that attempts have been made to employ aluminium for precipitating precious metals from acid or neutral solutions, but in this case it offers no advantages as compared with zinc and iron.

On the other hand, the practical precipitation of precious metals from alkaline cyanide solutions or sulphurised solutions by means of aluminium was not known, neither was it known that by the employment of the same in the presence of free alkali it was possible to obtain the important advantages hereinbefore set forth.

Of course, instead of the pure aluminium, alloys or an amalgam thereof can be used with a like advantage; furthermore, I do not confine myself to the use of the aluminium, its alloys, or amalgam in any special form, as it may be used in any suitable form without departing from my invention.

Having now particularly described and ascertained the nature of my said invention, and in what manner the same is to be performed, I declare that what I claim is,—

1. Extracting gold and other precious metals from their ores by subjecting the ores to the dissolving action of a cyanide of an alkali or an alkaline earth in the presence of an oxidizing agent, substantially as and for the purpose hereinbefore set forth.

2. Extracting gold from its ores by subjecting the ores first to the action of an acid and subsequently to the dissolving action of cyanide of an alkali or an alkaline earth in the presence of an oxidizing agent, substantially as and for the purpose hereinbefore set forth.

3. Extracting gold from its ores by subjecting the ores to the dissolving action of a cyanide of an alkali or an alkaline earth in a ball-mill, substantially as and for the purpose hereinbefore set forth.

4. Precipitating gold or other precious metals out of their solutions by means of aluminium, aluminium alloys, or aluminium amalgam, in the presence of a free alkali, substantially as hereinbefore described.

Dated 31st August, 1893. CARL MOLDENHAUER.

IMPROVEMENTS IN DISSOLVING GOLD AND OTHER METALS OUT OF ORES AND COMPOUNDS AND OBTAINING THE METALS THEREFROM.

I, Bernard Charles Molloy, member of Parliament, barrister-at-law, of the Middle Temple, London, England, do hereby declare the nature of my invention for "Improvements in dissolving Gold and other Metals out of Ores and Compounds and obtaining the Metals therefrom," and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention is a new method or process, which consists in, firstly, dissolving, by means of aqueous solvents, gold and other metals out of ores and other compounds containing these metals; secondly, precipitating the gold and other metals; thirdly, collecting the metals in mercury; and, fourthly, in some cases regenerating the original solvent and its compounds for reuse.

The solvents I prefer to use are chlorine, bromine, iodine, and cyanogen, and their compounds. The solvent may in some cases be obtained from its compounds by electrolysis, as described in FitzGerald and Molloy's British patent No. 1376, A.D. 1872, May 6th.

The general action of this process for extracting gold and other metals from ores and other compounds containing the same may be exemplified shortly by the following example of an ore from which gold is to be extracted. The crushed ore or other compound containing the gold to be extracted is placed in, say, an ordinary wooden or other suitable tank, and a quantity of a solution of the solvent, such as solutions containing bromine, chlorine, iodine, or cyanogen, is added. I will take for this example a solution of potassium-cyanide as the solvent. The quantity of the solvent added is proportioned to cover the varying quantity of metal to be extracted, and with an allowance, of course, for indirect action and loss, and the quantity of water about sufficient to moisten the ore. The quantity of solvent and of water will vary, and these quantities are easily settled by experiment. The added solvent then percolates through, or is otherwise brought into contact with, and in due course dissolves out, the metal, and combines with it to form in this case a cyanide of gold.

The action of this and the other solvents long in use require no particular description. The solvent, having dissolved out the gold, may then be drawn off for further treatment. The solution now holds the gold, not as metallic gold, but as a salt of gold—viz., in this case, cyanide of gold. The next step is to precipitate the gold. This precipitation is effected as follows: The gold solution is brought into contact with, or made to pass over or through, mercury contained in a suitable vessel. This mercury is charged either electrolytically with an alkaline metal, for example potassium, which, upon contact with the water of the gold solution, decomposes the water with the production of nascent hydrogen and an alkaline oxide of potassium, or the alkaline metal may be added by any other convenient means.

This electrolytic charging of the mercury with an alkaline metal will be dealt with herein. The nascent hydrogen combines with the solvent, forming another cyanogen compound—namely, hydrocyanic acid—and in so doing frees the gold from solution and precipitates it as a metal upon the mercury, which captures it, and from which it is easily obtained in the usual manner. The alkaline oxide then combines with the last cyanogen compound—namely, the acid—and regenerates or reproduces the original cyanide of potassium in solution, and which is then ready for reuse on a fresh charge of ore, and so on. Any cyanates present in the original impure cyanide salt will also be converted into cyanides. In this manner the gold is brought into solution, precipitated, collected, and the original solvent solution is regenerated or reproduced for further use. In the above case the electrolyte I prefer to use in electrolytically charging the mercury is potassium carbonate. It is evident that the reactions will differ somewhat with the solvent used, but the

following will sufficiently define the last-stated case, and indicate my method. The reactions are coterminous, but are separated for facilitating explanation :—

$$H_2O + O + 4KCN + 2Au = 2[KAu(CN)_2]\,2KOH$$
$$2[KAu(CN)_2] + 2H = 2KCN + 2CNH + 2Au$$
$$2CNH + 2KOH = 2KCN + 2H_2O.$$

The oxygen O in first equation may be supplied by any ordinary method—namely, atmospheric air, peroxide of hydrogen, or other suitable means.

In some cases these several solutions containing the gold and other metals are acid, but under the action of this process these solutions are rendered neutral and then alkaline, so that the solutions are, or become, alkaline solutions of the metals which are soluble in alkaline solution.

Apparatus of many forms of construction, and under many and differing conditions, depending on the character and quantity of the work required to be done, may be used, and therefore I do not confine myself to the use of any particular form of apparatus for the purpose. The solution, containing the metals extracted, is brought into contact with a body of mercury charged with an alkaline metal, say potassium. The alkaline metal rises to the surface of the mercury, and decomposes the water of the solution, the potassium combining with the oxygen of the water to produce an oxide of the alkaline metal, and the hydrogen (nascent) being set free from the surface of the cathode. The oxide of the alkaline metal renders the solution alkaline; the nascent hydrogen separates the gold and other metal from the cyanogen compound, as explained above, and the oxide of the alkaline metal reconverts the cyanogen compound into the original or similar salt.

The electrolytic charging of the mercury with the alkaline metal may be effected as described in my patents, granted by the United States of America, dated and numbered respectively 13th December, 1883, No. 290259, and 24th May, 1887, No. 363412, or in any other convenient manner.

The object of obtaining the nascent hydrogen in this case is not to keep the mercury from sickening, this not taking place in the presence of the cyanogen salt, but especially for the reducing action on the solvent salt. Thus, while I prefer the electrolytic method, I do not confine myself to that method of production. In carrying out this process I use a solution of bromine, chlorine, iodine, or cyanogen, or their compounds, or combinations of the same, as may be advisable in different cases. I do not, of course, claim any exclusive right to use the solvents herein mentioned, as they are well known and public assolvents, but only as part of a new process and combination.

Having now described the character of my invention for dissolving out gold and other metals from ores and compounds containing the same, and their precipitation and collection of such metals, and in some cases the reproduction of the original solvent solution, and indicated how it may be effected, what I claim is,—

1. The method of extracting gold and other metals from ores and other compounds by (*a*) dissolving out the metals by solvents and obtaining the metals in solution; (*b*) causing such solutions containing the metals to come into contact with a body of mercury in a vessel; (*c*) charging the mercury with an alkaline metal produced in the anode chamber, using the mercury as the cathode and a suitable anode resting in the electrolyte; and a current of electricity, and so (*d*) producing nascent hydrogen and an oxide of the alkaline metal on the surface of the mercury, over which the solution passes, the hydrogen and the oxide of the alkaline metal being obtained by the decomposition of the water of the solution by the action thereon of the alkaline metal in the mercury; (*e*) rendering the solution alkaline by the oxide of the alkaline metal; (*f*) precipitating the metal out of solution by nascent hydrogen on to the mercury; (*g*) amalgamating the precipitated metal in such mercury.

2. The method of precipitating gold and other metals from solutions containing them by rendering such solutions alkaline, if not previously so precipitated, the metals therefrom by nascent hydrogen, and amalgamating the precipitated metals with mercury containing an alkaline metal.

3. The method of precipitating metals from solutions containing them by rendering such solutions alkaline and precipitating the metals out of solution by nascent hydrogen.

4. The described process of extracting gold from its ores and compounds by means of a solvent of gold, an oxide of an alkaline metal, nascent hydrogen, a suitable mercury cathode, and an anode, and a suitable aqueous electrolyte in conjunction with a current of electrical energy.

5. The herein-described method of extracting gold and other metals from ores and other compounds by dissolving out the metal by any suitable salt of cyanogen, and the reproduction of the cyanogen salt decomposed by the nascent hydrogen in precipitating the metal by an oxide of an alkaline metal obtained by the decomposition of the water of the solution by the action thereon of alkaline metal previously introduced into the mercury.

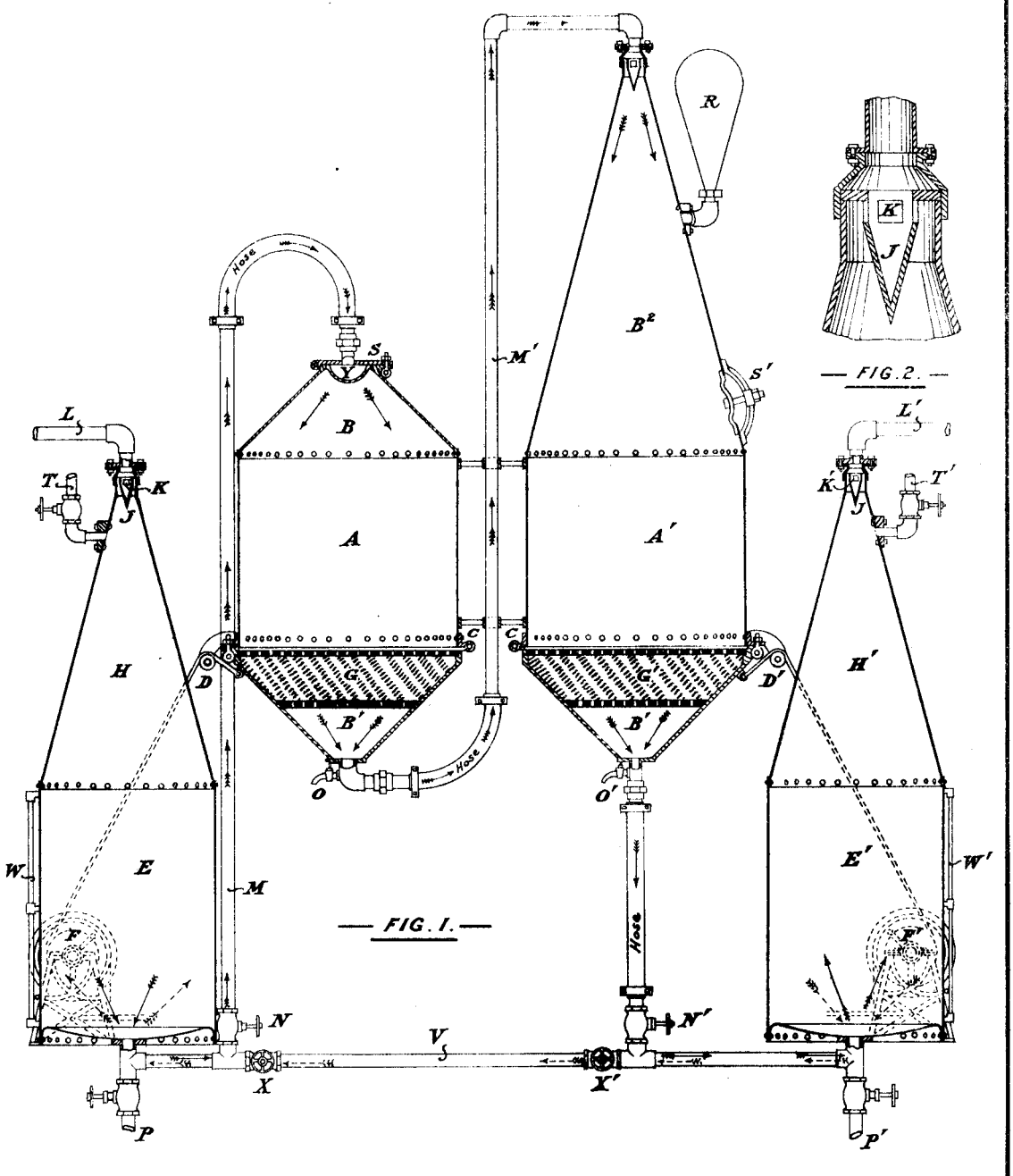
I certify this to be a true copy. BERNARD CHARLES MOLLOY.

IMPROVEMENTS IN EXTRACTING GOLD AND SILVER FROM ORES AND THE LIKE.

We, John Stewart Macarthur, managing director of the Cassel Gold-extracting Company (Limited), and Charles James Ellis, technical chemist to the said company, both of 157, West George Street, Glasgow, in the County of Lanark, North Britain, do hereby declare the nature of our invention for "Improvements in extracting Gold and Silver from Ores and the Like," and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement :—

Our said invention relates to what is known as the "Macarthur-Forrest process" for extracting gold and silver from ores and the like by means of cyanides, and has for its object to increase the efficiency and economy of that process in cases in which, from the nature of the ores treated or other circumstances, it is found that, in the solution of cyanide as heretofore used, there is formed,

— IMPROVED APPARATUS —
— FOR —
— DISSOLVING, LEACHING & FILTERING. —
— STORER & LACEY'S PATENT —



— FIG. 1. —

— FIG. 2. —

C. H. P. del.

or becomes present, a sulphide soluble therein which retards and objectionably affects the action of the cyanide on the precious metals.

Our invention consists in removing or rendering inert such sulphide by adding to the solution of cyanide, or to the ore, or to the mixture of ore and cyanide solution, a suitable salt or compound of a metal which will form with the sulphur of the sulphide a sulphide which is practically insoluble or inert in the cyanide solution, or which will materially diminish the objectionable action.

In carrying out our invention, we may use any one or more of various metallic salts or compounds, of which the following may be mentioned by way of example, preference being given to them in the order in which they are noted, namely: Salts or compounds of lead, such as plumbates; carbonate, acetate, or sulphate of lead; or salts or compounds of other metals, such as sulphate or chloride of manganese, zincates, oxide or chloride of mercury, and ferric hydrate or oxide. The proportion to be used in any case will depend on the proportion of soluble sulphide which has to be dealt with in the cyanide solution applied to the particular ore, and is easily and most conveniently ascertained by trials of a few small samples in each case. In the case of some ores containing sulphur, we find that the addition of salts or compounds, as and for the purpose hereinbefore referred to, and especially those of lead and mercury, increases the percentage of precious metals obtained.

Having now particularly described and ascertained the nature of our said invention, and in what manner the same is to be performed, we declare what we claim is,—

1. In the Macarthur-Forrest process for extracting gold and silver from ores and the like, the addition to the cyanide solution, or to the ore, or to the mixture of ore and cyanide, of salts or compounds of lead, substantially as and for the purposes hereinbefore described.

2. In the Macarthur-Forrest process for extracting gold and silver from ores and the like, the addition to the cyanide solution, or to the ore, or to the mixture of ore and cyanide, of any one or more of the metallic salts or compounds hereinbefore indicated, and capable of forming insoluble sulphides, as and for the purposes hereinbefore described.

JOHN STEWART MACARTHUR.
CHARLES JAMES ELLIS.

Dated 29th June, 1893.

AN IMPROVED METHOD OF, AND APPARATUS FOR, DISSOLVING, LEACHING, AND FILTERING.

We, John Storer, of Sydney, in the Colony of New South Wales, consulting chemist, and Benjamin Thomas Lacy, of San Francisco, California, one of the United States of America, mining engineer, do hereby declare the nature of our invention for an improved method of, and apparatus for, dissolving, leaching, and filtering, and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to an improved method of, and apparatus for, dissolving, leaching, and filtering various substances or mixtures—as, for instance, in the treatment of ores and minerals for the extraction of their metal contents by "wet methods," in the production of chemical substances, in the treatment of the refuse of industrial works, in the treatment of sewage, and in other treatment of other materials or mixtures requiring to be dissolved, leached, or filtered. By this invention economy in working and greater speed are effected in the solution, leaching, and filtration of all substances or materials requiring to be so treated, or to separately undergo each such process.

This improved method of dissolving, leaching, and filtering consists in the forced circulation in closed vessels, by means of direct steam or gaseous pressure, of the solvent or leaching liquid, or material to be filtered, as the case may be; and the improved apparatus consists of specially-devised closed vessels, and of special combinations and arrangement of said vessels, with valves and connections, by means of which such method may be carried into practical effect.

But, in order that this invention may be clearly understood, reference will now be made to the drawings herewith, in which Fig. 1 is an elevation partly in section of an improved apparatus for carrying out the improved method or process of dissolving, leaching, and filtering; and Fig. 2 an enlarged sectional elevation of a steam-distributor.

A A^1 are vessels or tanks into which the material to be operated on is charged. Each tank is preferably cylindrical, with ends B B^1 B^2 tapered as shown. These ends, like the body of the tanks, are flanged and fixed to the body in any convenient way. The bottoms B^1 are hinged at C to permit of easy emptying. For that purpose the bottoms are lowered by chains worked over pulleys D D^1 from the winches F F^1, or from other suitable hoisting and lowering gear. After emptying, the bottoms are hoisted back into position and bolted. They are then ready for a fresh charge. Fixed near the top of the ends B^1 are false bottoms G G^1, such as are used in lixiviation or filtering, prepared as is customary, and covered with any desired cloth, sacking, or other suitable filtering medium. E E^1 are cylindrical vessels or tanks fitted with tops H H^1, preferably tapering 75° from the horizontal, as shown.

It is to be understood that one or more perforated plates might be used to act also as distributors of steam over the surface of the contents of the tanks. These may be fitted or rest upon internal flanges on the inner periphery of said tanks in any desired positions. An inverted cone J (as shown enlarged in Fig. 2), having also preferably a taper of 75°, as above, is fitted at the top of each tank H H^1. Each cone serves, in conjunction with the tops H H^1, as a "distributor" and equaliser of the steam pressure upon the surface of the liquid contents of the tanks E E^1. Steam is admitted into the "distributor" from the steam-pipes L L^1, and thence passed through inlets K (say three, equidistant from one another) into the tanks. The taper of 75° from the horizontal is that which in practice has been found to produce the best and most economical working-result, although we do not confine ourselves to that exact angle.

By using steam direct from a steam boiler, the arrangement detailed above is found to work in such a manner that, whatever the steam pressure from the steam boiler employed may be, a working equivalent result is obtained in the tanks E E^1, and therefrom by the connecting-pipes M M^1 to tanks A A^1.

This pressure on the tanks upon the dissolving, leaching, or filtering liquid with which the tanks E and E^1 are nearly filled forces said liquid into circulation, as directed by the regulation or adjustment of cocks or valves as herein set out. In the ordinary process the liquid passes from tank E into tank A, thence into tank A^1, and finally into tank E^1. From there, by closing valves or cocks N N^1 and opening valves or cocks X X^1, the liquid, by turning on the steam pressure from pipe L^1, is forced through pipe V into tank E, from which (cocks X X^1 being closed and cocks N N^1 opened) it again is forced through the circuit before detailed as often as may be wished, and until the desired result is obtained. The full-line arrows show the course of the liquid through tanks E A A^1 to tank E^1, whilst the dotted arrows show its course from tank E^1 to tank E. O O^1 are drain-taps to drain off solutions from the ends B^1 before emptying the solid contents which may be in tanks A A^1. From tanks E and E^1, or either of them, by means of steam pressure applied as before described, the liquid may be forced through pipes P and P^1, or one of them, as the case may be, to where desired for subsequent treatment. S S^1 are charging man-holes. T T^1 are pipes through which tanks E and E^1 are filled; they may also be used as steam-escape pipes. W W^1 are gauge-glasses to show levels of liquids. We do not confine ourselves to any one special material in the construction of the before-described apparatus, as the material employed in the construction may be suited to the character of the solution or solutions used in the operations to be performed; for example, iron may be used alone or lined with any material not appreciably acted on by the solution employed.

In the drawings an air-vessel R is shown, which may be fitted if and as desired, and a spreader Y may also be fitted into tanks of the style of A if wished. Tank A^1 is shown with a tapered top B^2, similar to tops H and H^1, which construction of tank is especially suitable for a type of apparatus in which it is desired to have only one tank to which the steam-pressure may be applied directly, but other apparatus may, if desired, have several tanks similar to tank A, with top B^2, worked in series.

It can easily be seen that, working as explained, various combinations of parts may be arranged to fit varying conditions. Where washing is required, the same procedure as with dissolving solutions is employed. If solutions or liquids containing insoluble or suspended matters require filtering, they may be filtered directly through filter-beds G G^1, the solutions or liquids being forced through from tank E.

We would have it understood that, though we have described our method and apparatus as carried out by means of steam-pressure, they may be operated with compressed air or other suitable expansible gas or vapour capable of giving the required pressure to act upon the non-compressible fluids.

Having now particularly described and ascertained the nature of our said invention, and in what manner the same is to be performed, we declare that what we claim is,—

1. The improved method of dissolving, leaching, and filtering, the essential feature of which is the admission of steam, gas, or vapour under pressure into a closed vessel or tank containing non-compressible fluid, whereby said fluid is forced through the material under treatment, or through filtering media, as the case may be, substantially as herein described and explained.

2. The improved method of dissolving, leaching, and filtering, in which steam, gas, or vapour under pressure is admitted into one or more closed tapered vessels or tanks upon non-compressible fluid therein, to force said fluid into circulation through other closed vessels or tanks containing material for treatment or filtering media, as the case may be, substantially as herein described and explained.

3. In apparatus for dissolving, leaching, and filtering by the method set forth, the construction of operating vessel or tank with a tapered end (preferably tapering 75° from the horizontal), and connected with the primary source or reservoir of pressure, substantially as herein described and explained.

4. In apparatus for dissolving, leaching, and filtering by the method set forth, the combination and arrangement with an operating-tank such as A^1, E, or E^1, having a tapering receiving end such as B^2, H, or H^1, of a tapered (preferably 75° from the horizontal) pressure-distributor such as J, having inlets such as K, substantially as herein described and explained, and as illustrated in the drawings.

5. In apparatus for dissolving, leaching, and filtering by the method set forth, the combination and arrangement with an operating-tank having tapered receiving end, such as B, of a pressure-distributor such as Y, substantially as herein described and explained, and as illustrated in the drawings.

6. In apparatus for dissolving, leaching, and filtering by the method set forth, the combination and arrangement with operating-tanks, such as A and A^1, of hinged or removable bottoms such as B^1, and devices for lowering and raising said bottoms substantially as herein described and explained, and as illustrated in the drawings.

7. Apparatus for dissolving, leaching, and filtering, by the method set forth, of the particular combination and arrangement all together of mechanical parts substantially as herein described and explained, and as illustrated in the drawings.

Dated this 7th day of October, 1893.

JOHN STORER.
BENJAMIN THOMAS LACY
(By his Attorney, FRED. WALSH).

IMPROVEMENTS IN AND CONNECTED WITH COAL-CUTTING AND LIKE MACHINES.

I, Frederick Hurd, of Manygates Park, Wakefield, Yorkshire, and of 11, Grittleton Road, St. Peter's Park, in the County of Middlesex, England, mining, civil, and mechanical engineer, do hereby declare the nature of my invention for "Improvements in and connected with Coal-cutting and Like Machines," and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement.

My invention relates to machinery or apparatus for sinking, tunnelling, undercutting, nicking-on-end, and other operations in connection with the excavating of coal or other minerals. By means of this invention mines can be worked with less expense and greater output than can be obtained by the methods at present in use. At the same time, the safety, confidence, and comfort of the workmen are secured, by relieving them of the most dangerous and laborious part of their duties.

My invention consists in the cutting and drilling mechanisms and their relative arrangements to the motor, and in the apparatus required with the machines to enable them (the motor and cutting and drilling mechanisms) to better carry out the various operations necessary for the excavating of coal or other minerals.

My invention is represented in the accompanying drawings, in which Fig. 1 is a plan of a coal-cutting or like machine, with most of the cutting and drilling mechanism broken away; Fig. 1^a is a plan mainly in section of the cutting and drilling mechanism, which completes the view shown at Fig. 1; Fig. 2 is a side elevation partly in section, and Fig. 3 is an end-view of the same with parts removed; Fig. 4 is an end-view of parts shown at Fig. 1^a, looking at the drilling-end of the cutter-bar; Fig. 5 is an internal view of the cover carrying the bearings of the reciprocating motion, worm-wheel, and shaft; Figs. 6 and 6^a represent the cutter-bar drill, which is drawn in three parts for convenience in drawing; Fig. 7 is an end- or face-view of the auger or drilling-cutter; Fig. 8 is a cross-section of the cutter-bar drill, and Fig. 9 is a plan showing one form of cutter and method of fixing the same in the cutter-bar; and Fig. 10 is a face-view of the cutter separately. Other forms of cutters and methods of fixing the same are shown at Figs. 11 to 20. A modified form of cutter-bar drill is shown at Fig. 21. Fig. 22 is a plan of parts of a coal-cutting or like machine similar to that shown at Figs. 1 to 3, but slightly modified in parts; Fig. 23 is a sectional plan of parts showing the cutter-bar drill, provided with a screw-feed; Fig. 24 is a sectional plan of parts, showing the cutter-bar drill without feed-motion, and in combination with a cleaning-bar; and Fig. 25 is a sectional elevation of drilling and cutting mechanism for a tunnelling- or sinking-machine. Fig. 26 is a perspective view of my cutting-machine, showing it performing the work of undercutting; and Fig. 27 is a perspective view representing my improved cutting-machine as applied to heading or tunnelling. In all the figures like parts are indicated by similar letters of reference.

In applying my invention for undercutting, I actuate, by a motor A, constructed according to the specification of an application filed simultaneously herewith, a combined cutter-bar drill a, formed of forged or cast steel, or other suitable metal or alloy, and having separate or detachable chilled-steel or chilled-iron cutters a^1 fixed along its fluted or twisted periphery, and an auger-cutter a^2 at its outer end; the cutter-bar drill a is caused to revolve and reciprocate in a twisted or rifled sleeve b, having rifled grooves b^* for the passage of the cutters on the bar, and a key b^1 cast in it, which fits the twisted groove a^4 of the cutter-bar drill a; the sleeve b forms the boss of the wheel b^2, by which it is rotated by a bevel-pinion c^1 fixed on the motor-shaft c. I preferably use double helical teeth for the wheel b^2 and pinion c^1, but other suitable gearing may be employed; the wheel b^2 may be keyed or otherwise fixed on the sleeve b, instead of being cast thereon. The rear end of the cutter-bar up to the first cutter is bored out so as to give a free outlet to the cuttings when nicking-on-end or otherwise. The cutters a^1 may be fixed to the cutter-bar drill a according to any of the methods shown at Figs. 6 to 21.

According to the method shown at Figs. 8, 9, 10, I form a number of dovetail recesses a^3 at intervals along one edge of the twisted groove a^4. I form the shanks a^5 of the cutters to fit the recesses a^3, and they are retained in position by a split-pin a^6 fitting in a hole bored partly in the side of the shank a^5 and partly in the side of the dovetail recess a^3.

According to the method shown at Figs. 11 and 12, the cutter-shank a^5 extends into a hole drilled in the cutter-bar down to a little below the bottom of the twisted groove a^4, and in such case the upper part of the shank a^5 fits in a dovetailed or other recess a^3 formed in the upper edge of the twisted groove. In this case the cutter is held in position by a split-pin a^6 passing through an angular hole drilled through the cutter-shank a^5 and the bar a, and springing into a countersink. If desired, the lower end of the shank a^5 may also be formed with an eccentric stud or prolongation a^7, to enter a corresponding hole in the cutter-bar a to assist in holding the cutter from rotation in its recess.

According to the method shown at Figs. 13, 14, 15, the shank a^5 of the cutter fits into a hole bored in the cutter-bar, as described with respect to Figs. 11 and 12, but it is held in position and free from rotation by a split-pin or spring-shank a^6 passing into an eccentric hole in the bar a, one side of the said split-shank being hooked to catch under the bottom of one side of the eccentric hole a^8. If desired, the cutter may be formed as shown by dotted lines in Fig. 13 and full lines in Fig. 14, with a backward extension a^9 to give strength to the working part thereof.

According to the method shown at Figs. 16 and 17, the cutter a^1 has the shank a^5 fitting an angular or circular recess formed in the bar a; the eccentric stud or prolongation a^7 fits a corresponding hole, and it has a split pin or shank a^6 extending from its bottom end and passing through a hole formed for it in the bar a, as described with respect to Figs. 13, 14, 15.

The method shown at Figs. 18, 19, 20 is similar to that described with respect to Figs. 11 and 12, except that the eccentric stud or prolongation a^7 is dispensed with, and the cutter is held from rotation by the rear part of the cutter-head entering a recess in the cutter-bar, and such cutter is held in position either by an angular split-pin a^6 or by a split pin or shank a^6, extending from the bottom of the cutter-shank and springing into a countersink, and if desired the said split-shank a^6 may be eccentric to the cutter-shank a^5.

Fig. 21 represents a cutter-bar drill a, provided with two twisted grooves a^4, and fitted with cutters a^1 of the form shown, but which may be of any of the forms previously described, so far as such are suitable to the said doubly-grooved bar. The auger-cutter a^2 is formed as shown with a

central cutter and with two forward- and two backward-acting cutters, so that the auger shall cut both in its forward and backward motions.

In using this machine the operations are as follows: When the machine is brought up to the face of the coal or mineral to be operated upon, the cutter-bar drill *a* is set in motion, and while revolving it is fed into the face of the mineral by an automatic or hand-feed motion, which latter is shown on the drawings at Figs. 1ª and 23, and consists of a circular rack a^{10}, as shown at Figs. 1ª and 6, or a screw rack a^{10}, as shown at Fig. 23, which may be either cast or cut on the cutter-bar *a*, or otherwise combined therewith, a pinion *d* being arranged to gear into such rack.

As shown in Fig. 1ª, the said pinion *d* has its axis d^1 formed square to receive a lever-handle, by which it can be rotated, but, if desired, it may be fitted with a ratchet-wheel and driving-pawl. The said pinion *d* is carried by a casting d^2 pivotted at d^3 to the cutter-bar bearing d^4, and such casting d^2 is fixed in working position by a bolt d^5 passing through a segmental slot d^6, so that by loosening said bolt the casting d^2 can be turned on its pivot d^3, and the pinion *d* removed out of gear with the rack a^{10}.

When the cutter-bar drill *a* has entered to the depth required it is locked by the blocks *e* of the reciprocating motion gear, and all strain or action taken off the feed-gear by removing the pinion *d* out of gear with the rack a^{10}. The reciprocating motion is obtained preferably by forming on the sleeve *b* a worm-thread b^3, into which gears a worm-wheel *f*, carrying on its gudgeon f^1 two crank-pins f^2, fitting into blocks f^3, which actuate two rocking-levers f^4. Fitting round the circular rack a^{10}, and embracing several rings of said rack, is the thrust-block *e*, which is in halves, each half being coupled by a right- and left-hand screw e^1. These divided thrust-blocks *e* are connected to connecting-rods e^2, operated by the rocking-levers f^4, which impart the reciprocating motion of the latter to the cutter-bar drill *a* when the thrust-block *e* and drill *a* are connected.

Instead of the divided thrust-block *e*, as described above, acting in connection with the rack a^{10}, it may act between two or more shoulders on the sleeve, and give motion to the cutter-bar drill through the intervention of the sleeve *b*, the sleeve in such case being capable of sliding through the bevelled wheel b^2.

The machine is traversed forward along the face of the mineral by means of a snatch-block and a hauling-drum *g* mounted on an axis g^1 passing through the axis of the switch *h*, the rope being wound on to the drum and passing around a snatch-block and then to a fixture on the machine, or such rope may pass direct from the hauling-drum to any fixture.

Instead of using the hauling-drum a chain-wheel and chain may be employed, but when working down hill or on a level, cranks g^2 fixed on the axis g^1 are used, and connecting-rods g^3 connect such cranks with the driving-wheels g^4. The casing *h* of the switch is fitted to the front trunk A^1 of the motor A, and the hauling-drum *g*, or chain-wheel and cranks g^2 and rods g^3, are driven from the motor-shaft *c* by means of worm- and spur-gearing and friction-cones as shown in Fig. 22, and described in my English specification, No. 1,036, of the year 1872. The cutter-bar drill at the same time revolves, thus cutting away the coal in front of it, while its reciprocating motion assists in breaking up the coal and dislodging any lumps of pyrites that may be met with.

In order that the coal or mineral may be nicked on end to expedite the breaking-down of the mineral when undercut, the cutter-bar drill *a*, with its sleeve *b* and feed-gear, are carried by a separate casting B, carrying the bearing B^1 for the motor-shaft *c*, and which is so arranged as to make a whole or partial revolution round the motor-shaft by means of a worm *i* and worm-wheel i^1. (See Figs. 1, 1a, 2, 22, 23, 24, and 25.) By this arrangement also the machine is enabled to cut either right or left hand, thus dispensing with a costly left-hand cutting arrangement, as required in other machines now in use.

In this class of machine, the vibration, when at work, is very great, and I reduce this greatly by fixing or constructing the journals to carry the cutter-bar drill *a* at an angle of about 80°, with the rails in the direction in which the machine is moving, as represented at Figs. 1ª, 23, and 24, thereby causing the machine to hold itself well up to its work.

I also provide the machine with rail slide-blocks *x* (see Fig. 3) in addition to the usual wheels g^4, which blocks, when at work, are let down onto the rails, and, by their large bearing-surface, give the machine more stability and greater steadiness.

The wheels g^4 and blocks *x* are provided with screws g^5 similar to those patented by me in England on the 3rd April, 1872, No. 1,036, for raising and lowering same, and so varying the height or angle of the cut, except that the screws are right and left threaded, so that when acting, to lower the block, they shall raise the wheels, and *vice versâ*; separate screws, however, may be employed.

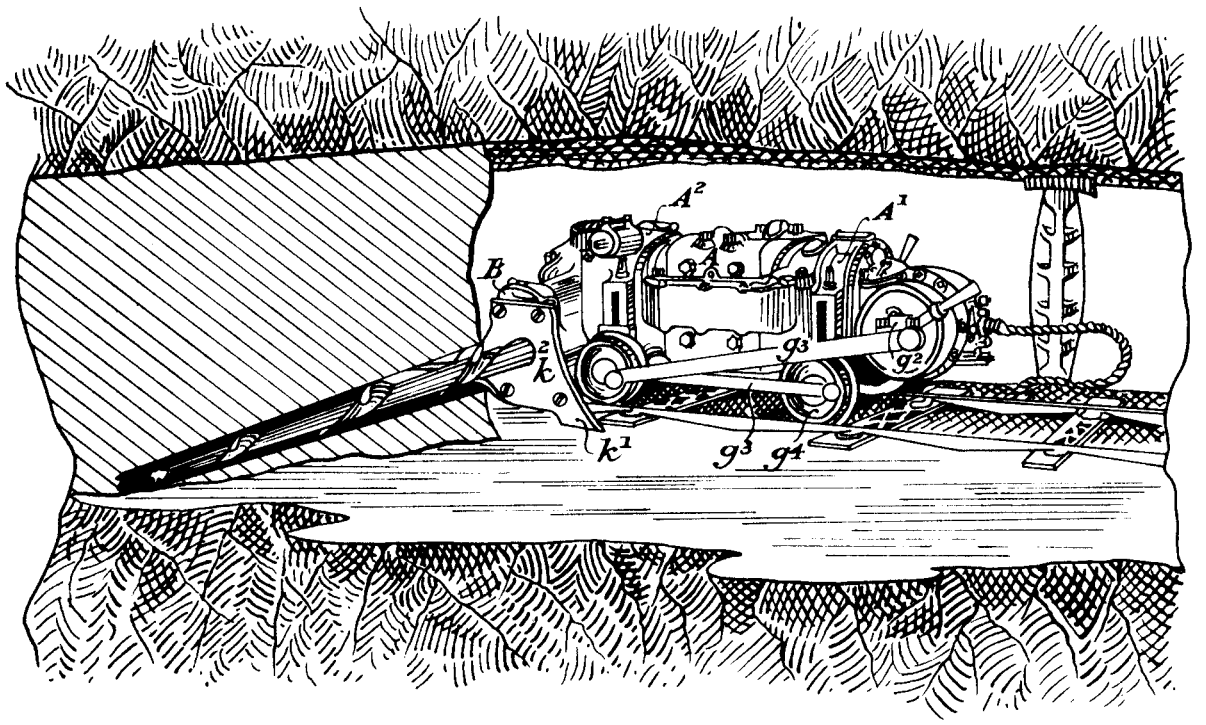
One set or pair of wheels g^4 and blocks *x*, and their respective raising-screws g^5, are attached to a separate casting C (see Figs. 1 and 22), made free to revolve, or partly so, round the outer portion of the leading trunk A^1 of the motor A, and are thus capable of adapting themselves to any unevenness of the rails on which the machine works; another set or pair of wheels g^4 and blocks *x*, with their respective screws g^5, are fixed or coupled to the back trunk A^2 of the motor A. (See Figs. 23 and 24.)

To take out the cuttings made by the cutter-bar drill I use a cleaning-bar *j* (see Fig. 24), preferably U-shaped in section, set at an acute angle to and behind the cutter-bar drill *a*, and fixed to the machine by suitable means when at work. The cuttings are caused, by the forward motion of the machine, to slide along the face of this cleaning-bar, and to be deposited between or at the side of the rails as the machine proceeds.

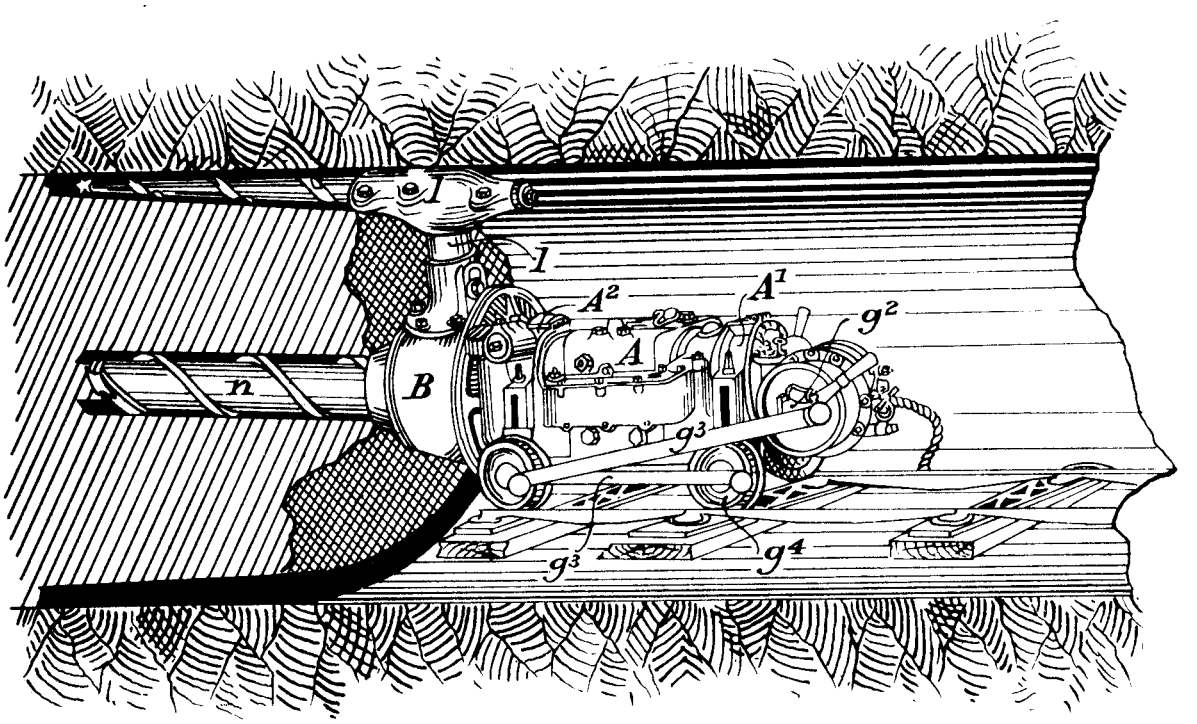
I remove irregularities from the face of the mineral, and from the bottom, by means of a fixed cutter *k*, shown at Fig. 1ª, and by dotted lines at Fig. 4 and at Fig. 26, attached to the front journal casting B of the cutter-bar drill *a*, the said fixed cutter *k* at the same time forming a cover for the thrust-block gear. This fixed cutter *k* has a cutting-edge k^1 to clear the bottom, and an inclined cutter-edge k^2 to remove projection on the face of the mineral sufficiently high to clear the cutter-bar bearing.

IMPROVED COAL-CUTTING MACHINE

— HURD'S PATENT —



— View showing Machine Undercutting. —



— View showing Machine Heading or Tunnelling. —

The fixed cutter k is also formed with an inclined grooved conductor k^3, so arranged as to carry the cuttings back over the cutter-bar front journal to the rear of the machine. By this means the machine is enabled to proceed with its work without stoppage.

In applying my invention to a machine for tunnelling or sinking, a slight modification of the machine before described is necessary, and which is illustrated at Figs. 25 and 27. In this case the cutter-bar drill a, with or without its reciprocating motion (in the drawing it is shown without), is fitted to the end of a telescopic arm l, carried by the centre casting B, which is free to revolve around the end trunk A^2 of the motor in a plane at right or other angles to the motor-shaft. The cutter-bar drill a is tapered down from its driven to its working end; it is driven by shaft m and bevel gearing m^1 m^2 from the motor-shaft through the sleeve b and gearing b^2 c^1, and is fixed to the telescopic arm l, which also forms a casing for the gearing, at such an angle that the tips of the cutters are located slightly beyond the plane of the casing l of the wheel m^2 and make a cut parallel to motor-shaft c; by this means clearance is obtained between the casing l of the bevel pinion m^2 on the cutter-bar drill a and the sides of the shaft or tunnel. By the centre-piece B which carries the telescopic arm l is also carried an externally rifled tubular drill n, similar to one patented by me in England, 27th August, 1880, No. 3,474. This drill n is driven from the sleeve b by bevel gearing n^1 n^2.

The mode of operation with this machine is as follows: The machine is brought up to the face of the mineral, and the centre-drill and cutter-bar drill a set in motion. The two drills are then led into the face by the entire machine being worked forward by means of hauling and a snatch-block or connecting-rod gear, hereinbefore referred to, to the full depth required. The centre-drill n is then stopped from rotating, and the centre casting B carrying the telescopic arm l is then caused to revolve, by means of worm gearing i i^1, driven by hand or from the motor-shaft. Thus the cutter-bar drill a is caused to cut a deep circular, oval, or square groove in the face of the mineral. This groove may be made of any desired shape by fixing one or two suitable templates or cams o on the trunk A^2 of the machine, by which the length of the telescopic arm l may be varied as the centre casting B revolves, and thus enable it to cut a square, oval, rectangular, or other shaped groove. Motion is given to the telescopic arm l by studs l^1 fixed therein, and provided with rollers working in the grooved cams o. The centre-drill n being allowed to remain in at full depth serves to steady the machine.

When a complete revolution has been made by the telescopic arm l carrying the cutter-bar drill a, the drills are withdrawn from the mineral by the machine being moved backwards away from the face of the mineral, which is then broken up to the depth of the cut, the centre hole greatly facilitating this operation. When the material is removed the machine is brought up to the face of mineral again and the operation repeated.

In sinking-operations the centre piece, carrying cutter-bar drill a, centre externally rifled tubular drill n, and mechanism before described, and the motor for driving the same, are mounted in a cage similar to the one patented by me in England on the 25th March, 1869, No. 906, the mode of operation being the same as described for the preceding machine.

It will be evident that the cutting mechanism herein described may be connected with and driven by a motor of different construction to that hereinbefore referred to.

Having now particularly described and ascertained the nature of my said invention, and in what manner the same is to be performed, I declare that what I claim is,—

1. The improved constructions and arrangements of coal-cutting and like machinery, substantially as herein shown and described.

2. In coal-cutting and like machinery, the improved construction of cutter-bar drill, and the methods of fixing the cutters therein, substantially as herein shown and described.

3. In coal-cutting and like machinery, the combination with a suitable motor and driving-gear of a rotating and reciprocating cutter-bar drill, having cutters on its length, and an end-cutter or auger, substantially as herein shown and described.

4. In coal-cutting and like machinery, the combination with a driving-shaft of a casting carrying the cutting mechanism, and capable of being rotated around the said driving-shaft by suitable gearing, substantially as herein shown and described and for the purposes stated.

5. In coal-cutting and like machinery, the combination of a cutter-bar drill, a rifled driving-sleeve to permit of the cutter-bar drill, with its side- and end-cutters, being fed through the sleeve, and mechanism for giving endwise motion to the cutter-bar drill, substantially as herein shown and described.

6. In coal-cutting and like machinery, the combination with suitable cutter or cutters of a cleaning-bar, arranged at an acute angle therewith, and acting to clean out the *débris* from the groove cut in the coal or other mineral, substantially as herein shown and described.

7. In coal-cutting and like machinery, the combination, with suitable cutting and driving arrangements, of a fixed cutter and inclined conductor, for cutting the face and bottom of the mineral, and for lifting or conveying the *débris* backward and over the cutter-bar journal, substantially as herein shown and described.

8. In coal-cutting and like machinery, the combination of a driving-shaft, a casting capable of being rotated around said driving-shaft, a telescopic arm carried by said casting, a cutter-bar drill carried by said telescopic arm, a central cutter or drill carried by the rotatable casting, and driving mechanism for rotating the cutter-bar drill and central drill, substantially as herein shown and described.

9. In coal-cutting and like machinery, for tunnelling or sinking the combination with a telescopic arm carrying a drill or cutter, of a cam or cams acting to give a to-and-fro motion to the telescopic arm to control the shape of the groove cut in the coal or mineral, substantially as herein shown and described.

Dated the 4th day of October, 1893. FREDERICK HURD.

COLLIERY VENTILATING MACHINERY.

There needs no elaborate argument to explain why colliery ventilation by machinery came into use. Every since the introduction and successful application of the steam-engine we have lived in an age of increasing mechanical appliances, and it was inevitable that the same power which had proved so effective for pumping the water, and for hauling and winding the coals, should also be adopted for the purposes of producing the huge volumes of air, not only enormously greater in bulk but much greater in weight than the water and the coals combined. The quantity of air represented by 200,000 cubic feet per minute is not excessive, but it weighs not less than 400 tons an hour, and even for an eight-hours day amounts to more than 3,000 tons a day.

Pumps.—It was, perhaps, not unnatural that the inclination of colliery authorities and colliery engineers, whose minds were being directed to mechaninal ventilation, should be in the direction of pumping appliances. This class of machinery had been exceedingly effective in keeping our mines free of water, and there seemed no good reason at first sight why a similar appliance should not answer for pumping the air out and through the workings of a mine. The first attempt at a ventilating-machine on anything like a large scale was the Struvè ventilator. It is not certain that there are any now working in the United Kingdom. We had gigantic pumps like small gasometers attached vertically at the ends of two beams, the opposite end of which received motion from a steam-engine piston. The engines and pumps were placed vertically, and there was a clack arrangement not unlike that of an ordinary water-pumping system, but, of course, much larger. The Sturvè ventilator proved that ventilation could be performed by machinery; but it might have been evident, and probably was evident, that the reversing of these gigantic pumps twice in each revolution, and the constant opening and closing of the large and heavy clacks, caused serious wear-and-tear, resulting in frequent repairs, and made anything like high speed impossible. An appliance of a somewhat similar character, which bore the name of Nixon, was introduced, and was simply a horizontal application of the Struvè principle. Instead of the pumps working vertically they worked horizontally, and were supported on wheels moving to and fro upon rails. Apart from the objection that has been mentioned, it will be readily understood that, in the event of an explosion occurring at the moment that either of these pumps or pistons were approaching the pit-shaft, the shock and effect of the machinery would be very serious, and, even if an explosion took place when they were receding from the pit-shaft, the explosion would tend to accelerate their motion to such an extent that the consequences would be disastrous.

Definite-volume Ventilators.—Another class of ventilating machinery which was tried came under the head of those known as definite-volume exhausters, which sweep out a fixed volume of air each revolution. We have this class exemplified in the Lemielle, the Fabry, the Cook, and the Root. Some of these had doors and levers, which adjusted themselves during the revolution, so as to fit with the needful tightness against the well in which they worked, and prevent, so far as possible, leakage. Others were wheels or portions of wheels revolving upon each other within the well, so as to sweep out the air, and thus produce the current, but all these appliances proved only very moderately effective, and were very cumbersome. On the larger scale which was necessary for the production of large volumes, they were found incapable of working at the necessary speed, and this, together with their liability to get out of order, prevented their coming at all extensively into use.

Centrifugal Fans.—We thus arrived by somewhat gradual stages at the third and most important, and now practically universal, ventilating-machine, known as the fan, which acts upon the centrifugal principle. The special advantage which attaches to all ventilating-fans is that we have no valves or clacks, and no levers or rods, and no pumps or pistons. We have simply a revolving wheel, which is always working in one direction, and consequently, if well made, can run practically at any speed; and, as the effect of the fan is produced by centrifugal force, and as this centrifugal force depends upon the speed, this is, of course, an enormous advantage. We may divide centrifugal ventilators into two great classes—namely, (*a*) Those which are called open-running, by which we mean that they are free to discharge their air all round the circumference; and the other class (*b*), known as closed fans, by which we mean those that are not free to discharge their air into the open all round the circumference.

Dealing first with open-running fans, the first large ventilating-fan for a colliery, so far as I know, was introduced by the distinguished engineer, Naysmith. It had an inlet on each side, and the fan itself consisted of a number of straight radial blades revolving vertically between a fixed casing on each side. About the same time there was an open-running ventilator placed on a vertical shaft and revolving in a horizontal plane. As first designed, the air entered underneath, and blades, shaped like the sails of a windmill, passed it through and discharged it on the upper side. Afterwards, the principle was altered. The blades were made straight and radial. The top was closed, and the discharge took place round the circumference. In the Biram fan we had a somewhat new departure, not in the sense of revolving in a vertical plane between the fixed casing on both sides, because that applied to the Naysmith-fan, but the blades were numerous and limited in depth, not being more than one-tenth of the radius, and the blades were inclined backwards, so that a line at right-angles from the root of one blade touched the tip of the next. The Waddle fan was on entirely different lines. It was self-contained, in the sense that the whole machine revolved, and there was no fixed casing. The air entered on one side and passed through curved and gradually narrowing passages to the circumference. The blades at first were simply inclined backwards, the alternate blades extending not more than half the distance between the circumference and the inlet. The passages, by their contraction, were made so that the circumference at any point, multiplied by the cross-sectional area at that point, was a constant quantity. In later forms of the Waddle fan, the blades are uniform in length and curved backwards, these blades stopping short of the outer circumference, which is bell-mouthed. In the Marsden fan the communication between the inlet

and the outlet for the discharge of air is by means of a series of pipes or tubes of equal cross-sectional area from inlet to outlet, and curved backwards. The Hopton open-running fan, which has quite recently been introduced, has an inlet on each side, a central diaphragm, and the blades curve backwwards and run into the circumference practical tangential. It would be scarcely possible to design or construct a simpler fan than the one identified with the name of Hopton. The revolving portion, consisting of the arms and the blades, works between two brick-walls, and I can well imagine that the cost of construction and erection will be small.

In dealing with closed-running fans: The Guibal has always been a more or less massive structure of considerable breadth as well as of diameter, and receives air on both sides, or on one only. The blades are inclined backwards, and curved at the extremities, so that the tips are radial. This fan revolves in a fixed easing at the sides and for most of the circumference, the clearance being as little as possible, except for a certain distance at the bottom, through which the air is discharged, the amount of opening being regulated by an adjustable shutter into a gradually enlarging chimney. The Cockson fan is virtually a Guibal fan, with a modification that the blades contract in width towards the tips, and the passage for air is uniform through the fan. The inventor and patentee (Mr. Cockson), after very careful consideration and elaborate experiment, satisfied himself that the proportioning of the blades according to his design enabled the Guibal fan to work at a higher velocity and increases the useful effect. The special improvement giving rise to the name of the Walker-Guibal was in the shutter, which, instead of the original rectangular form with the upper edge horizontal, was made after the manner of an inverted elongated V—thus Λ, In the ordinary Guibal each blade has the maximum resistance to face in approaching the upper edge of the shutter-opening, and has the least resistance immediately on passing that opening. The result is an injurious rebound for every blade in every revolution. The anti-vibration shutter identified with the name of Messrs. Walker Brothers avoids this. The result was that vibration ceased, and practically a silent fan was produced, enabling a higher speed and less wear-and-tear. In the Schiele type of centrifugal ventilator we have a backward inclination of the blades; which, in the modern designs, has assumed a curvature, also backwards. The blades are contracted in width from inlet to outlet, and the fan (that is, its revolving part) is surrounded by a spiral casing, into which the air discharges all round the circumference, the space constantly increasing until it reaches the chimney. The Walker indestructible fan has blades curved backward from within the inlet to the circumference. The air is received on both sides, and there is an especially strongly constructed central diaphragm built up with separate layers of plates, and altogether a very strongly-made appliance. The spiral casing, which forms a portion of this arrangement, does not entirely envelop the revolving part, and the improved shutter referred to forms part of the arrangement. This fan, although recently introduced, has already established itself in various parts of the United Kingdom, and promises, in addition to the excellent results obtained, to fulfil the name it bears. In the Capell ventilator we have a combination. The central portion is a drum which receives the air on both sides. Within this drum we have blades curved backwards, and apertures in the circumference between each pair of blades, through which the air passes into the outer chamber, in which we also have blades curved backwards. The revolving portion of the arrangement includes the sides of the fan, and the air is discharged all round the circumference through a spiral casing into an enlarging chimney. The Johnston, which is a very recent form of ventilator, is the result of numerous experiments made as to the form of the blades and the design of the fan generally. The width is much less than in other fans, and the air is received on both sides. The blades are straight, and inclined backwards. They revolve within a fixed casing at each side, and discharge into a spiral casing which rapidly increases in area. The chimney is a very large one, simply clearing the top of the fan, and a considerable portion of this chimney is immediately over the fan. In the Ratêau centrifugal ventilator we have the usual spiral casing and the enlarging chimney, which seems to rise much higher, in proportion to the size of the fan, than in any other arrangement. The general outline is not unlike that of the Waddle fan, but the blades are much more numerous, and these blades extend practically to the centre of the fan, and have a peculiar curvature slightly forward, and also a curvature in the line of the fan shaft. Immediately in front of the blades there is a cone, terminating in a point.

Open Running and Closed Running.—Having briefly and generally described a considerable number of the best known types of centrifugal ventilators of the two great classes of open-running and closed running, a few remarks may be made as to the aims and principles of both classes. They agree as regards the endeavour to admit the air from the upcast shaft into the fan easily, to pass the air through the fan with as little resistance as possible, and also to discharge the air from the fan easily; in these points lie the whole object of the fan. As to the inlet, that may be and should be the same in both. Regarding the passage of the air through the fan there is an important difference. An open-running fan must, to be efficient, discharge the air at a very low velocity, because, as is well known, the energy of bodies in motion increases, not merely as the velocity, but as the square of the velocity, and the energy in the discharged air is so much useless work. To overcome this, the passages in the more correct open-running fans, in my opinion, are curved backwards. The difficulty that I have always felt is that the air cannot be discharged from a fan without possessing considerable velocity, and in that must rest to that extent a defect in all open-running fans. As regards the outlet, my opinion is that as exactly the same quantity of air must leave the fan that enters it, the passages from inlet to outlet should be of uniform capacity throughout. Now, we consider the closed running fan, and the special advantages of this class, when properly designed, are, to my mind, very great. They have equal facilities with open running as to inlet. They are equal to open running in regard to free passages through the fan, and blades can be curved backwards. They possess the enormous advantage that the air may be discharged from the fan at a high velocity without any material loss of energy. The gradually increasing capacity into which they discharge reduces the velocity, utilises the energy of the motion of the air,

and the air is ultimately sent out into the open at such a speed that practically no resistance is experienced and no inrush of air is possible.

Fan Construction.—Simplicity should never be lost sight of, and strength should always constitute a first consideration. These two virtues ensure what is so desirable in colliery appliance—continuity of work, and non-liability to get out of order. There has always been an objection, which has increased as time went on, to "mammoth" slow-running fans. They are cumbersome in themselves. They absorb power by the movement of themselves. They are costly to make. They occupy much space, and necessitate extensive and expensive foundations and houses. The entry of the air to the fan should be easy, which means large inlets having a clear course, not baffled by projecting arms or cones, or even blades "veed" towards the centre. The inlet should be on each side of the fan, with a central diaphragm to prevent the two currents conflicting. The passage of the air through the fan should be easy, which means that there should be sufficient and not excessive fan-capacity. In open-running fans the blades should be so formed that the air may pass through as nearly in a straight line as possible and leave the circumference with as little circumferential velocity as may be, because all velocity of discharge in open-running fans represents a loss of energy. This means that in open-running fans the blades should have considerable backward curvature, and the number of blades should not be too great, producing by their surface excessive friction and drag upon the air. The conclusion to be arrived at is that the inlets and the outlets, and the circumference of the inlets, multiplied by the width, and the total blade-surface, should represent equal quantities, and that the circumference of the fan at any point, measured by its width at that point, should be an equal quantity, In a closed-running fan the cirumstances are somewhat different, because the energy of discharging air can be utilised after leaving the fan in diminishing the pressure outside the fan, and thus expediting the delivery from the fan. The curvature backward of the blades need not, in consequence, be so great as for an open-running fan. The air should be free to leave the fan at any point of the circumference, and the spiral casing all round should be continued into the chimney. But the quality in proporion of the inlets to the fan, the passage into the body of the fan, the passage through the fan, and the discharge from the fan, should be equal, as in the open running. The sides of the revolving parts should be enclosed, preventing leakage, and only allowing discharge at the circumference. The journals and bearings of the fan should be so perfectly constructed that they fit exactly, and can revolve without heating at practically any speed. The engine which drives the fan should be designed on lines by which the highest economy in the use of steam can be obtained. The engine should work with a high pressure of steam, because it is only with high-pressure steam that we can get the maximum economy. The engine should be compound, to admit of the highest range of expansion, and discharge the exhaust into the condenser at the lowest possible pressure. Excessive speed in the engine is undesirable, and to enable a moderate speed of the engine and a high speed of the fan the power should be transmitted by rope gearing. An approximately perfect ventilating arrangement would be two fans, each with its own engine, but, in any case, there should be duplicate engines. On such lines as have been sketched, we are likely to have at our command the highest type of ventilating-fan. For further improvements in the production of great volumes of air, with a comparatively small expenditure of coal and power, we shall have to look, not so much to improvements upon our present fans, as improvements in the arrangements of the mine itself.—*Colliery Guardian.*

IMPROVEMENTS IN THE METHOD OF PRODUCING CRUDE ANTIMONY.

The question of making antimony mining in New Zealand a successful venture hinges greatly on the expense of smelting the ore and refining it so as to make it into star metal fit for the Home market. This has to be done in three stages—first, converting it into crude antimony; second, into bowl metal; and third, into star metal. The first process has hitherto been the greatest source of expense. The crude antimony has hitherto been made in crucibles, and several methods have been tried to produce the crude metal in a furnace, but without success. Some years ago the Endeavour Inlet Antimony Company constructed a description of reverberatory furnace to smelt the ore into crude metal: this proved a failure. They afterwards erected a large furnace with retorts, but had no better success. Since the present company has owned the property a water-jacket furnace was erected to smelt the ore; but this also proved a failure. At last, Mr. Seager, an ironfounder at Wellington, has devised a means of producing crude antimony by a cheap process.

The method adopted by Mr. Seager consists of a series of cast-iron pipes set vertically into a furnace. These pipes are 12in. in diameter and 4ft. in length, made of very hard white metal, about 1½in. in thickness, and are open at the top and bottom; but, in order that the ore may not fall out until it is melted, each of the pipes has a false bottom, and when charged with ore they have also a tight-fitting cover placed on top. The false bottom does not fit close inside the lower part of the pipe; a small space is left, so that the ore as it melts drops into a mould or trough which is placed underneath the furnace; and when the whole of the ore is melted the false bottom is allowed to drop out, and the whole of the charge is taken out of the pipe, which is again filled with another charge of ore. Mr. Seager informed me that the pipes have been used for about ten weeks in the furnace, and seem to stand very well; also, that with one cord of firewood for fuel he can produce one ton of crude antimony.

Hitherto, the action of the sulphur in the antimony has been the means of destroying all the substances used in retorts and furnaces, and if retorts of hard white cast-iron can be made to stand for a reasonable time it will effect a revolution in antimony-mining, as the crude antimony can be produced by Mr. Seager's method at a much less cost than formerly, and possibly other mines which are at the present time standing idle will be again taken up and be made remunerative for working.

TABLE OF USEFUL CALCULATIONS FOR PIPES.

HYDRAULIC MEAN DEPTH in Inches and Feet, AREA in Square Inches and Square Feet, of PIPES from 6in. to 36in. in Diameter; and VELOCITIES of WATER in PIPES from 6in. to 36in. in Diameter when carrying from One to Fifteen Sluice-heads of Water. (One sluice-head = one cubic foot per second.)

Diameter.		Hydraulic Mean Depth.		Area.		Velocity, in Feet.													
In.	Ft.	In.	Ft.	Sq. In.	Sq. Ft.	One Head.	Two Heads.	Three Heads.	Four Heads.	Five Heads.	Six Heads.	Seven Heads.	Eight Heads.	Nine Heads.	Ten Heads.	Eleven Heads.	Twelve Heads.	Thirteen Heads.	Fourteen Heads.	Fifteen Heads.
6	...	1·50	0·12500	28·27	0·1963	5·0942	10·1884	15·2826	20·3768	25·4710	30·5652	35·6594	40·7536	45·8478	50·9420	56·0362	61·1304	66·2246	71·3188	76.413
7	...	1·75	0·14583	38·48	0·2672	3·7425	7·4850	11·2275	14·970	18·712	22·455	26·197	29·940	33·682	37·425	41·167	44·910	48·652	52·395	56·138
8	...	2·00	0·16666	50·26	0·3491	2·8645	5·7290	8·5935	11·458	14·322	17·187	20·051	22·916	25·780	28·645	31·509	34·374	37·238	40·103	42·967
9	...	2·25	0·18750	63·61	0·4418	2·2635	4·5270	6·7905	9·0540	11·317	13·581	15·844	18·108	20·371	22·635	24·898	27·162	29·425	31·689	33·951
10	...	2·50	0·20833	78·54	0·5454	1·8335	3·6670	5·5005	7·3340	9·1675	11·001	12·834	14·668	16·501	18·335	20·168	22·002	23·835	25·669	27·502
11	...	2·75	0·22917	95·03	0·6599	1·5153	3·0306	4·5459	6·0612	7·5765	9·0918	10·607	12·122	13·637	15·153	16·668	18·183	19·698	21·214	22·730
12	...	3·00	0·25000	113·09	0·7854	1·2732	2·5464	3·8196	5·0928	6·3660	7·6392	8·9124	10·185	11·459	12·732	14·005	15·278	16·551	17·825	19·098
13	...	3·25	0·27083	132·73	0·9217	1·0849	2·1698	3·2547	4·3396	5·4245	6·5094	7·5946	8·6792	9·7641	10·849	11·933	13·018	14·103	15·189	16·274
14	...	3·50	0·29167	153·93	1·0689	0·93554	1·8710	2·8066	3·7421	4·6776	5·6131	6·5486	7·4842	8·4197	9·3553	10·290	11·226	12·161	13·097	14·033
15	...	3·75	0·31250	176·71	1·2272	0·81486	1·6297	2·4445	3·2594	4·0743	4·8891	5·7040	6·5188	7·3337	8·1486	8·9634	9·7783	10·593	11·408	12·222
16	...	4·00	0·33333	201·06	1·3962	0·71623	1·4324	2·1486	2·8649	3·5811	4·2973	5·0136	5·7298	6·4460	7·1623	7·8785	8·5947	9·3109	10·027	10·743
17	...	4·25	0·35416	226·98	1·5762	0·63443	1·2688	1·9033	2·5377	3·1721	3·8066	4·4410	5·0754	5·7099	6·3443	6·9788	7·6132	8·2476	8·8821	9·5165
18	...	4·50	0·37500	254·46	1·7671	0·56589	1·1317	1·6976	2·2635	2·8294	3·3953	3·9612	4·5271	5·0930	5·6589	6·2247	6·7906	7·3565	7·9224	8·4884
20	...	5·00	0·41667	314·16	2·1816	0·45837	0·91674	1·3751	1·8334	2·2918	2·7502	3·2085	3·6669	4·1253	4·5837	5·0420	5·5004	5·9588	6·4171	6·8756
22	...	5·50	0·45833	380·13	2·6398	0·37881	0·75762	1·1364	1·5152	1·8940	2·2728	2·6516	3·0304	3·4092	3·7881	4·1669	4·5457	4·9245	5·3033	5·6821
24	...	6·00	0·50000	452·39	3·1416	0·31831	0·63662	0·95493	1·2732	1·5915	1·9098	2·2281	2·5464	2·8647	3·1831	3·5014	3·8197	4·1380	4·4563	4·7746
26	...	6·50	0·54167	530·93	3·6870	0·27122	0·54244	0·81366	1·0848	1·3561	1·6273	1·8985	2·1697	2·4409	2·7122	2·9834	3·2546	3·5258	3·7970	4·0683
28	...	7·00	0·58333	615·75	4·2760	0·23386	0·46772	0·70158	0·93544	1·1693	1·4031	1·6370	1·8708	2·1047	2·3386	2·5724	2·8063	3·0401	3·2740	3·5079
30	...	7·50	0·62500	706·86	4·9087	0·20371	0·40742	0·61113	0·81484	1·0185	1·2222	1·4259	1·6296	1·8333	2·0371	2·2408	2·4445	2·6482	2·8519	3·0557
32	...	8·00	0·66666	804·24	5·5851	0·17904	0·35808	0·53712	0·71616	0·89520	1·0742	1·2532	1·4323	1·6113	1·7904	1·9694	2·1484	2·3275	2·5065	2·6857
34	...	8·50	0·70833	907·92	6·3050	0·15860	0·31720	0·47580	0·63440	0·79300	0·95160	1·1102	1·2688	1·4274	1·5860	1·7446	1·9032	2·0618	2·2204	2·3791
36	...	9·00	0·75000	1017·87	7·0685	0·14147	0·28294	0·42441	0·56588	0·70735	0·84882	0·99029	1·1317	1·2732	1·4147	1·5561	1·6976	1·8391	1·9806	2·1221

GOLD-MILLING ORES IN THE AUSTRALASIAN COLONIES.

In an article in the *Engineering and Mining Journal* it states that New Zealand, producing nearly 15 per cent.tof the Australasian gold output, has a great variety of ores, a fact which would suggest a more marked diversity in the methods of treatment than actually obtains. On the west coast of the South Island, at Reefton more especially, the gold comes from quartz ores of comparative simplicity, and the stamp mill does fairly good work. The same may be said of the southern province of Otago, though in the latter region much value has been for ever lost by an omission to save the pyrites by concentration after ordinary battery and plate amalgamation. In the North Island, at Hauraki or the Thames, the ores are very complex, and the stamp mill is in vain attempting to do satisfactory work under almost hopeless conditions. Wet methods of reduction have survived long after they were unfitted to obtain an economic extraction of the values of the ore. In the neighbouring districts the cyanide process has been employed, with very varying success.

The three leading milling centres in Victoria—namely, Bendigo, Ballarat, and Clunes—have many features in common, but Clunes is the only one which can show a mill at all completely equipped. There are no rock-breakers and no automatic ore-feeders in use either in the Bendigo or Ballarat districts, though at Clunes they were introduced as early as 1865. The absence of these very necessary parts of a complete stamp mill is an evidence of an obstinate disregard of modern progress in milling methods which is as regrettable as it is inexplicable.

In New Zealand, Otago and the Thames—one in the South, and the other in the North Island—are in some contrast. The southern province use methods which originated largely from the experience obtained at Clunes. Gold-saving by blankets can be seen contrasted with the more modern plate amalgamation. The ore carries a noteworthy percentage of pyrites, which in many instances is known to lock up value. The not unfrequent absence of any attempt at concentration is therefore very noticeable. It is, however, largely explained by the fact that there are no works in the Island which treat concentrates, and, as a consequence, they have to be sent to Australia at a cost in shipping charges, &c., which is almost prohibitory.

Going to the North Island, we find the *reductio ad absurdum* of stamp milling in the treatment of the complex gold- and silver-ores of the Thames district. Here the mill stuff carries free gold, native silver, native arsenic, sulphides of silver and antimony, arsenical pyrites, galena, tellurides of gold and silver, and other minerals, in great complexity and variety. This material is subjected to stamp milling, followed by blankets whose washings are treated by grinding and amalgamation in pans. The result of this process is that barely 50 per cent. of the values are saved, and the subsequent treatment of the tailings is almost as remunerative as that of the ore itself. This is an instance of the blind disregard of the first axiom of all successful milling—namely, to adapt the process to the ore.

The North Island of New Zealand contains many very valuable depositories of the precious metals, but they are too often found locked up in refractory matrices. At Kuaotuna, Karangahake, Te Aroha, Waihi, Waiorongomai, Puhipuhi, Kapanga, and other localities with picturesque Native names, there are ore-deposits which have as yet baffled the metallurgical ingenuity. In this mining region, as has been the case elsewhere, large and costly plants have been erected before those in charge had proper assurance of the capability of the mine to supply the ore required by the mill, or the capability of the mill to satisfactorily treat the ore. The handsome concentrating and cyanide leaching plant of the Sylvia Company on Tararu Creek is an instance of the former; and what little now remains of the extensive concentrating and smelting plant of the Te Aroha Gold and Silver Company, at Waiorongomai, is an example of the latter.

The cyanide process has been struggling here for many years. It was first introduced at the Crown Mine, Karangahake, and battled in vain against incompetency and ill-luck. At the present time it is being used with varying success at several milling establishments in this region, but, in addition to the ordinary difficulties common to new leaching processes, it has to bear the incubus of an extortionate royalty.

There is a great deal of truth in what the writer of the article says in reference to gold-milling, but he is evidently a little at sea when he states that native silver, native arsenic, and tellurides of gold and silver are found in the Thames ores, and having to acknowledge that there are ore-deposits in this region which have as yet baffled the best metallurgical ingenuity he cannot show the remedy of the evil he complains of. It is very easy to pull a thing to pieces, but it often requires considerable skill to build it up again. However, the article and the remarks on the methods of gold-milling in New Zealand are well worth reading. It tends to point to acknowledged defects, and no doubt the time is not far distant when some of these will be remedied. The great object is the getting of a cheap method of extracting the gold and silver from our North Island ores. It is generally of low grade, and will not pay for an expensive method of treatment. The cyanide process has effected a considerable saving in the percentage of gold and silver extracted, but there is plenty of ore which would not pay to work by this process of treatment.

There is one other country in the world where gold is found in the same formation and in similar condition to that of the Hauraki Goldfield, and that is in Hungary. In that country the gold is so finely disseminated through the stone, and in combination with so many minerals, that it is difficult to save a fair percentage of the precious metals the ore contains.

The gold mills on the Hauraki field that have been erected of recent date are much better equipped than the old mills, and some of them are quite as complete as the American, and it is questionable if they do not save a larger percentage of gold, notwithstanding the fact that the ore is complex and refractory. To take the mill of the Waihi Gold and Silver Company at Waihi, where about 90 per cent. of the assay-value of the gold is obtained, the saving is all that can be expected; it is only a question whether the same percentage could be saved at a less cost of treatment. There is no comparison as regards the efficiency between the more recent erected gold-mills in the North Island and those in the South, especially the Achilles Company's mill at Skipper's.

If mills of this type were used at the Thames not over 25 per cent. of the assay-value of the gold would be obtained. At many of the mills in the South or Middle Island, if the ore was carefully sampled and assays made, mill-men would find that comparatively a small percentage of the gold was recovered.

The principle still generally adhered to in hand-breaking the quartz and hand-feeding is bad in the extreme. If the stamps are to do proper duty rock-breakers have to be used. These are by far the best and most economical machines for reducing the ore to a uniform size. It is well known that when hand-feeding is done lumps of quartz are shovelled into the mortar, and this not only reduces the crushing-capacity of the stamps, but tends to break the screens and increase the cost of same, and when the ore is properly sized in the first instance an automatic ore-feeder will feed the stamps more regular than hand-feeding. It is considered by many of the present mill-men that hand-feeding is a work that can be done by boys, and, indeed, a great many boys are employed at this work, for the reason that they cost less than men, but it cannot be said to be a saving, but it is the same in this as in many other things—"a penny wise and pound foolish." We can never expect to treat our low-grade ores, which in New Zealand are in abundance, unless all the labour-saving appliances are used in reduction and system of treatment.

There is no doubt many of the present mining companies are fully aware of this, but, having mills erected which have been used for many years, they are not constructed in such a manner to admit of rock-breakers and ore-feeders being attached. The battery-house and framing would have to be altered, and this would entail a considerable outlay; and companies which are only paying the actual expenses of working their mines do not believe in making calls to do any work they can possibly do without, even should such work prove of future advantage. Neither do the companies who are working their mines at a profit put away any money as a reserve fund to do dead-work of any description. All the profits are paid away in dividends, and shares change hands so often that a new class of shareholders come in; and, when the calls have to be made, they are, in many instances, unable to meet them, and a good property is in many instances sacrificed owing to the want of funds to develop it.

In regard to the working of stamp batteries and hand-feeding, Mr. T. A. Rickard, in an article in the *Engineering and Mining Journal* of New York, states that boys at £1 per week wages for hand-feeding batteries are put down as inexpensive extras, but in a year the wages paid to them make a sum greater than is required to purchase and erect a full equipment—namely, six effective ore-feeders and a rock-breaker of such capacity as would break a twenty-four hours' supply of ore in ten hours, leaving the pulley which drives it by day free to operate a dynamo to illuminate the mill by night.

The economy is not that of labour only, but it affects the wear-and-tear considerably. When there is a large quantity of stuff in the mortar the stamps fall dead on it, and does very little work, the material forming a cushion for the stamps, and sending rough material against the screens, which cuts holes in them, causing new ones to be used before the old screens are really worn out. If the large lump of hard quartz is fed into the mortar, and the one side of the stamp-shoe falls on it, the jar is such that tends to break the shank near the stamp-head. The stamps should never have more than from 1½in. to 2in. of material under them. The blow is then sharp and effective, and to insure this the ore from the mine must first be put through a rock-breaker and sized before allowing it to go into an automatic feeder.

It is quite a pleasure to go into either the Crown Company or the Waihi Company's mills. The stamps are fed regular, and the whole of their machinery is like a piece of clockwork. These companies both adhere to dry crushing, and find that system the most advantageous to adopt for the class of ore there is to deal with. The whole of the ore in the Hauraki Goldfield is more or less complex; it has a certain percentage of silver, as well as gold, and, combined with other minerals, the ore is not suitable for chlorination, even if the expense of that process was much less than it is. One of the Newberry-Vautin plants was erected at the Thames some years ago, and proved an entire failure in treating the ores from that field. The building and roasting-furnace stand there as a monument of folly.

The best system of treating the North Island ores that has yet been tried is dry pulverising and leaching with a crude cyanide-potassium solution. The great drawback to this system is the royalty charged for its use by the Cassel Company, owing to their having obtained a patent for its use in this colony, a patent which should never have been granted in the form it was. They were entitled to a patent for their system of application, but not for using any substance containing a compound of cyanogen. According to the *Engineering and Mining Journal* of New York, of the 11th November last, a large company in South Africa is going to erect an extensive plant to treat the ore with a cyanide solution, and going to test the patent rights of the Cassel Company. The article referred to is as follows: "The success of the cyanide process in South Africa, especially in the Wetwatersrand Mine, has encouraged its trial by other companies in that region, who do not acknowledge the validity of the MacArthur-Forrest patents. Our London correspondent writes that the Consolidated Goldfields Company is preparing to put up a cyanide plant at its mines in the Transvaal, and is preparing to fight the African Gold Refining Company, which owns the patents." And in the same *Journal*, of the 13th January last, it states that certain companies have set up cyanide plants on their own account, without consulting the African Gold Recovery Company; and the latest news on this point is that the company referred to is not going to pay any dividend this half-year, in order that it may have plenty of money to pay for impending litigation. The article further states, "That the struggle is near at hand is evident from the fact that a barrister well known in the patent law courts has just sailed from London for South Africa to look after the company's interests." If the patent is proved to be invalid in South Africa, the time is not far distant when it will be tested here. Were it not for the excessive royalty the process would be more largely adopted.

HISTORY OF THE CYANIDE PROCESS.

It may be interesting to quote an article out of the "Mineral Industries of the United States" for 1892, written by Louis Janin, jun., showing the rise and progress of the cyanide process for the treatment of gold and its ores:—

It is difficult to find a period in the history of chemistry since the radical cyanogen was discovered in which the solvent-power of potassium-cyanide on gold has not been mentioned. Hagen, as early as 1805 ("Unbersucheugen," vol. i., p. 665), states that gold is dissolved not only by free chlorine and *aqua regia*, but by a potassium-cyanide solution. Gsnelin says, probably quoting from Elssner's "Researches," that cadmium, silver, and gold are dissolved by potassium-cyanide in the presence of air. Glassford and Napier were also aware that cyanide of potassium dissolved gold, and published the fact in 1844 (Phil. Mag., vol. xxv., p. 64). In the French edition of Thompson's "Chemistry," published in 1807, and in Proast's paper on "Facts for the History of Prussiates" ("Annales de Chimie et de Physique," 1806, vol. ix., pp. 225–249), the prussiate of potash is stated to be a solvent of gold.

Elkington, in 1840 (see English patent specification No. 8,447 for that year), was, however, the first to make practical use of this reaction in his galvano plastic-operations. He dissolved either oxide of gold or metallic gold in a state of fine division in a 20-per-cent. solution of potassium-cyanide. Faraday, in the "Transactions of the Philosophical Society" for 1857, describes an experiment made in 1856, in which he used a diluted solution of cyanide of potassium for dissolving gold.

As a practical application of this process to the reduction of ores, it is found that United States Letters Patent No. 61,866, dated 5th February, 1867, were issued to Julo H. Rae, of Syracuse, New York, for the treatment of auriferous and argentiferous ores by cyanide of potassium. In brief, Rae's method consisted in treating the ores with a solution of potassium-cyanide aided by the electric current, and in a subsequent electrolytic precipitation of the metals from the cyanide solution. Even at that date, the use of potassium-cyanide was not considered new. Patents for the use of potassium-cyanide in metallurgical operations were also issued to Clark, No. 229,586, in 1880; and to Faucett, No. 236,424, in 1881. John F. Sanders, of Ogden, Utah, received patent No. 244,080, dated 12th July, 1881, for a composition consisting mainly of potassium-cyanide for dissolving the coating from the gold of the so-called coated gold-ores, preliminary to pan-amalgamation. In this method he unknowingly dissolved the gold as well as the coating, and reprecipitated it by the aid of the iron of the amalgamating-pan and the mercury employed. Although these patents show the antiquity of the process, that of Rae in particular, covering any claim to the use of potassium-cyanide as a solvent of gold, as found in ores, none were pushed to any practical success. Like a thousand other patents, they were suffered to slumber without any pronounced effort being made to introduce any of them into the field of metallurgy.

At length an inventor, Jerome W. Simpson, of Neward, N.J., came who had studied more thoroughly the details of metallurgical processes, and, with a clearer idea of what was needed, he secured a patent, which, if untenable, was at least more comprehensive, more clearly worded, and more successful when introduced into practice than any which had preceded it. Simpson's patent (No. 323,222) was issued on the 28th July, 1885, and in his specifications he says,—

To carry my invention into effect, I first grind or crush the ore containing the metal to be extracted to a powder of more or less fineness. This powder is then treated with certain salts in solution adapted to combine chemically with the metal in said ore, and form therewith a soluble salt. After thorough agitation, to mix the solution with the ore, the mixture is allowed to stand until the solid matter is settled, and the solution has become clear. I then suspend a piece or plate of zinc therein, which causes the metal dissolved in the salt solution to be precipitated thereon, from which it can be removed by scraping, or by dissolving the zinc in sulphuric or hydrochloric acid. The precipitated metal may then be melted into a button. The salt solution I use for dissolving the metal from the ore is composed of 1lb. of cyanide of potassium, 1oz. of carbonate of ammonia, ½oz. chloride of sodium, and 16 quarts of water, or other quantities in about the same proportions. This solution is particularly adapted for ores containing gold, silver, and copper in the form of sulphurets. For an ore containing gold and copper only I use cyanide of potassium and carbonate of ammonia about in the proportions named. For ores rich in silver I employ a proportionately larger quantity of chloride of sodium.

I am aware that cyanide of potassium, when used in connection with an electric current, has been used for dissolving metals, and also that zinc has been employed as a precipitant, and the use of these I do not wish to be understood as claiming, broadly. I am also aware that carbonate of ammonia has been employed for dissolving such metals as are soluble in a solution thereof, and the use of this I do not claim. But what I claim as new is,—

1. The process of separating gold and silver from their ores, which consists in subjecting the ore to the action of a solution of cyanide of potassium and carbonate of ammonia, and subsequently precipitating the dissolved metal, substantially as set forth.

2. The process of separating metals from their ores, to wit, subjecting the ore to the action of a solution of potassium, carbonate of ammonia, and chloride of sodium, and subsequently precipitating the dissolved metals.

While Simpson added sodium-chloride to his solution undoubtedly for the purpose of chloridizing a portion of the silver, the use of ammonium-carbonate is somewhat hard to understand. It will be observed that Simpson distinctly states that he does not claim the use of zinc as a precipitant and admits its prior use. He admits also that his claim for the use of potassium-cyanide, as a solvent, is extremely weak, and relies mainly upon the combination in solution of the several chemicals.

A caveat in the names of F. U. Eudlich and U. H. Müblebnerg, covering the use of potassium-cyanide for the extraction of silver and gold from their ores, was filed in the spring of 1885, but a patent was not secured, and the matter is still pending.

In 1885 a series of experiments was made in San Francisco with potassium-cyanide, and in 1886, when in Utah, another series, the results of which were published in the *Engineering and Mining Journal* for the 29th December, 1888. A caveat was filed on the 1st May, 1886, but this also was not pushed to the taking out of a patent, although my results were good with both gold and silver-ores.

The history of potassium-cyanide as a solvent for gold has thus been followed up to the period of Messrs. MacArthur and Forrest's experiments in Glasgow, which are said to have occupied over three years before and after the issue of their English patent (No. 14,174) on the 19th October, 1887. After patenting their process in England—the particulars of which will be described later on—they applied for patents in nearly every other country which contains gold and issues patents. Their application for an American patent was dated in November, 1887, but their claims were so badly worded and so ridiculously comprehensive, and their discoveries withal so ancient, that, after numerous emendations and modifications of their claims, their patent (No. 403,302) was not granted until the 14thMay, 1889, when their claims were limited to the use of a dilute solution of potassium-cyanide, described as follows:—

The invention consists in subjecting the auriferous or argentiferous ores to the action of a solution containing a small quantity of cyanide, as hereinafter set forth, without any other chemically active agent, such quantity of cyanide being reckoned according to its cyanogen, and the cyanogen being proportioned to the quantity of gold or silver, or gold and silver estimated by assay or otherwise to be in the ores under treatment. By treating the ores with the dilute and simple solution of a cyanide, the gold and silver are obtained in solution, while any base metals in the ores are left undissolved, except to a practically unappreciable extent; whereas when a cyanide is used in combination with an electric current, or in conjunction with another chemically active agent—such as carbonate of ammonium, or chloride of sodium, or phosphoric acid—or when the solution contains too much cyanide, not only is there a greater expenditure of chemicals in the first instance, but the base metals are dissolved, to a large extent, along with the gold or silver, and, for their subsequent separation, involve extra expense, which is saved by our process.

In carrying out our invention, practically we take the ore in a powdered state, and mix it with the solution of cyanide in a vessel made of, or lined with, any material not appreciably acted on by the solution. We regulate the quantity of cyanide so that its cyanogen will be in proportion to the quantity of gold or silver in the charge of ore, but in all cases we dissolve it in sufficient water to keep the solution extremely dilute, because it is when the solution is dilute that it has a selective action such as to dissolve the gold or silver in preference to the baser metals.

In dealing with ores containing 20oz. or less of gold or silver, or gold and silver per ton, we find it most advantageous to use a quantity of cyanide, the cyanogen of which is equal in weight to from one to four parts for every thousand parts of the ore, and we dissolve the cyanide in a quantity of water of about half the weight of the ore. In the case of richer ores, while increasing the quantity of cyanide to suit the greater quantity of gold or silver, we also increase the quantity of water, so as to keep the solution dilute. In other words, the cyanide solution should contain from two to eight parts by weight of cyanogen to a thousand parts of water, and the quantity of solution used should be determined by the richness of the ore. After the solution has been decanted or separated from the undissolved residues, the gold and silver may be obtained from it in any convenient way, such as evaporating the solution to dryness and fusing the resulting saline residue, or by treating the solution by sodium-amalgam.

Having fully described our invention, what we desire to claim and secure by letters patent is: The process of separating precious metal from ore containing base metal, which process consists in subjecting the powdered ore to the action of a cyanide solution containing cyanogen in proportion not exceeding eight parts of cyanogen to a thousand parts of water.

Some time after this patent was issued patents covering the use of zinc, preferably filiform, or thread-like, for a precipitating agent, and the use of caustic alkalies for neutralising ores, containing acids or acid salts were granted to Messrs. MacArthur and Forrest. It may be seen, therefore, that their patents cover substantially three points: The use of dilute solutions of cyanide—not more than eight parts of cyanogen to a thousand of water; the use of zinc, preferably filiform, as a precipitate; and the employment of caustic alkalies for neutralising an acid-ore. As shown in this record, these several claims were antedated by other inventors, and are not now patentable. For years zinc had been used by electroplaters for recovering gold or silver from cyanide solutions and on the 29th April, 1884, an English patent, No. 5,125, was issued to Astley Paston Price, of London, for certain improvements in the extraction of the precious metals from their ores, covering the use of zinc as a precipitating agent. His method of extraction, upon which he laid little stress, has no bearing on the case; but the manner of precipitation is of consequence. Mr. Price claims as follows:—

I wish it to be distinctly understood that I do not claim as any part of my invention the methods or processes for effecting the solutions of the gold or of the silver when contained in ores or metallurgical compounds or products; but what I do claim is effecting the precipitation of the precious metals—*videlicet*, of gold or of silver—resulting from the treatment, substantially as hereinbefore mentioned, or otherwise of ores of metallurgical products, such as or similar to those hereinbefore referred to, by the employment, when in a fine state of division, of zinc or of other metal or metals other than copper, which are capable of precipitating gold or silver, the same being brought in contact with the solution.

The use of caustic alkalies as neutralising agents is almost as old as the art of metallurgy itself, and, if it has not been patented before, it is not because it has not been known, but because few metallurgists are willing to claim as their invention what is known to the whole profession. It has been, however, made the basis of a prior and untenable patent by E. H. Russell for use in hyposulphite lixiviation. The narrow claim for the use of solution containing not more than eight parts of cyanogen (twenty parts of chemically pure potassium-cyanide and thirty parts of commercial cyanide) to a thousand parts of water is no better than Simpson's worthless claim

for a solution of definite proportions containing twenty-five parts of cyanide to a thousand parts of water.

In the writer's opinion, Messrs. MacArthur and Forrest have no claims whatever upon those who wish to use the process further than gratitude for having revived an old process and placed it in operation. In South Africa, favoured by ores extremely well adapted to the process, and by admirable business management, they have made an enviable technical and financial success, due credit for which must he given them.

Experiments on Silver Ores with Cyanide Solution.—In preparing the accompanying table the fact that laboratory tests, particularly in wet processes, have been recognised where excesses of chemicals are usually employed, are often misleading. The list given contains, however, nearly every variety of argentiferous and auriferous mineral found in our mining-camps, and the results indicate, in a measure, those that may be expected from similar ores, and allow us to draw interesting deductions as to the applicability of the cyanite process to various types of ores.

RESULTS of EXPERIMENTS made on Typical Silver-ores with Potassium-cyanide, compared with other Methods of Extraction.

Name of Mine.	Value of Ores —ounces per Ton.	Percentage extracted by Lixiviation with				
		Caustic Ammonia.	Concentrated Brine.	Hyphosulphite of Soda.	Russell Process.	Cyanide of Potassium.
Grand Central, Arizona ...	43·2	48·2	50·5	86·6	93·7	92·6
Silver Reef, Utah	45·0	20·0	36·9	50·7	77·8	82·8
Horn Silver, Utah	184·0	56·6	74·2	81·6	90·7	93·6
Tybo, Nevada	20·0	...	8·0	30·0	58·0	71·8
Sombretillo, Mexico... ...	80·4	6·7	3·4	75·1	84·0	97·3
Ramshorn, Idaho	89·6	2·2	11·8	34·4	50·5	80·0
Broken Hill, New South Wales	24·8	67·0	...	84·3	97·0	99·7
Broken Hill, New South Wales	34·0	12·8	...	43·2	57·0	84·6
Bullionville, Nevada ...	10·0	...	...	...	35·0	32·0
Bertrand and Geddes, Nevada	176·4	...	...	...	11·1	11·8
Argenta, Montana	75·2	...	...	...	12·2	5·7
Belmont, Nevada	20·0	...	...	...	20·0	35·0
Belmont, Nevada	510·8	...	...	...	37·2	47·5
Las Vedras, Mexico... ...	130·0	...	...	...	4·6	41·5
Ontario, Utah	80·8	...	...	...	44·0	72·5
Daly, Utah	74·0	...	...	...	17·0	81·1
Albert Silver-mine, South Africa	30·0	...	...	...	...	...

The general characteristics of the various ores tested are, briefly, as follows:—

Sample No. 1 is typical of the upper-level ores of the Grand Central Mine, one of the Tombstone (Arizona) group. The ores of these mines, although largely siliceous, contain considerable quantities of lime and manganese. The silver minerals are principally cerargyrite and argentite. These have been considered typical free-milling ores, although it is doubtful if over 84 per cent. has been recovered by raw pan-amalgamation, and at times the percentage has fallen appreciably below this. Poor results were locally ascribed to the presence, in increased quantities, of molybdate of lead or manganese dioxide.

The silver in sample No. 2 from the Christy Mine, Silver Reef, Utah, is found as chloride, sulphide (in smaller quantities), and metallic silver, in a gangue of sandstone somewhat discoloured by carbonate of copper. These ores are worked by the free-milling pan-amalgamation process, yielding at the Christy, Leeds, and Starmont Mills about 75 per cent. of their value. The Russell process was also tried, but, owing to the increasing percentage of metallic silver, comparatively insoluble in cuprous hyposulphite solution, it had to be abandoned. In none of the experiments made by me on this class of ore was the extraction by cyanide of potassium less than 80 per cent.

The Horn Silver ore (sample No. 3) contains, like all the surface-ores of that mine, large quantities of chloride of silver readily soluble in cyanide solution, or, indeed, in any of the other solutions tried. This particular sample contains but little lead, and that in the form of cerusite.

The ores of Tybo, Nevada, are among the most difficult of Western ores to treat, even after roasting, during which they suffer a severe loss, only about 85 per cent. of the value of the roasted pulp being recovered. The mineral is principally a complex sulphide and falilore, so that the extraction of 71·8 per cent. is a remarkably good result.

The Sombretillo ore (sample No. 5) is principally, if not entirely, chloride of silver, the gangue being siliceous. The phenomenally good results obtained with this ore, as shown in the table, are, therefore, not to be wondered at.

The Ramshorn ore (sample No. 6) contains both galena and carbonate of lead, the silver being associated mainly with the lead mineral, although some is contained in the accompanying pyrite and zinc-blende.

Sample No. 7 is the rich kaolin ore from the Broken Hill deposits, in the Barrier Range, New South Wales. The occurrence of silver in this ore is peculiar. It is in the form of embolite or chloro-bromide of silver, disseminated throughout the whittish mass, and concentrated on the surface of the quartz and garnet crystals which it contains. These crystals are proportionately richer than the surrounding mass. This ore was tested in vain for iodine, although, on the authority

of C. A. Luckhardt, it is present. This is, of course, a typical free-milling ore, 95 per cent. of its value being extracted from amalgamation.

Sample No. 8, while of a different quality, is from the same mine. It is a siliceous iron-ore, carrying some 38 per cent. FeO. The results obtained with it, although good, were not so satisfactory as with the preceding sample.

The Bullionville tailings (sample No. 9) are the result of several workings, having been amalgamated at least twice, and partially concentrated. They contain 10 per cent. of carbonate of lead, some galena, and considerable iron in a siliceous gangue. Tests by amalgamation and lixiviation gave poor results, and by the cyanide solution still poorer were obtained. It is reported that certain tailings at Bullionville, upon being tested by cyanide solution, yielded 10oz. of silver and 90 per cent. of the gold. As the average grade is about 12oz. of silver and 2dwt. of gold, these results are doubtful.

The Bertrand and Geddes ore (sample No. 10) contains antimoniate of lead, with which silver was combined. As amalgamation gives poor results. The process adopted is to chlorodize the ore in Bruckner cylinders, and leach by hyposulphite of soda or lime. This method extracts about 84 per cent. of its value.

The Argenta ore (sample No. 11) from Beaverhead County, Montana, contains over 40 per cent. lead, and is unworkable by any process except smelting.

The Belmont ores (samples No. 12 and 13) contain arsenical pyrites, pyrite-blende, and galena, with the silver in fahlore and arsenical and antimonial ruby forms. They are worked by the usual chloridizing, roasting, and amalgamation process, although recently a lixiviation plant has been erected.

The Las Vedras ore (sample No. 14) contains large quantities of carbonate of lime, with the silver in the form of ruby silver and arsenical pyrites. The ore is worked by chloridizing, roasting, and subsequent lixiviation with hyposulphite of soda.

The Ontario and Daly ores (samples 15 and 16) contain the silver principally in the form of fahlore, more or less decomposed. The following are analyses :—

	Ontario.	Daly.
Silica	75·0	76·60
Zinc	5·73	5·30
Lead	1·80	3·50
Iron	2·80	1·65
Sulphur	2·23	0·70
Lime (CaO)	1·76	1·32
Magnesia (MgO)	0·23	Trace
Copper	0·29	0·39
Silver (oz.)	39·50	39·10
Gold (oz.)	0·044 ($0·91)	0·044 ($0·91)

They gave excellent results by amalgamation or lixiviation after a chloridizing roast.

Sample No. 17 was tested by Mr. Bettles, of the Robinson Gold-mining Company, South Africa. It contained 10 per cent. of copper, which interfered with the extraction of the silver, which was in the form of a sulphide.

Ores have been tested containing varying percentages of copper, but thus far have not met with *so pronounced a difficulty*, although it is easy to imagine that, should the energy of the cyanide be neutralised by dissolving more soluble minerals, the extraction of the silver or gold must suffer.

Conclusions and Deductions.—The conclusions and deductions to be derived from a study of the foregoing are that silver in oxidized surface-ores, or where it occurs as a chloride, is readily attacked by cyanide of potassium, and that where no minerals were present which exert an unfavourable influence this method may prove economical. It must be confessed, however, that, even with these conditions, it has but a limited range of usefulness. On the other hand, where lead, oxide of copper, or certain oxides of iron occur, the results are so poor as to preclude the use of the process.

The results obtained from different samples of silver-ore from the same mine vary greatly, for a slight increase of an undesirable element which would not affect amalgamation in the slightest degree, causes a great decrease in the percentage of extraction by cyanide.

The following results obtained from the raw ore of the Daly Mine at different dates, between which the variation in its constituents was but trifling, illustrates this :—

Date.	Extracted.	Date.	Extracted.	Date.	Extracted.
	Per Cent.		Per Cent.		Per Cent.
April 10 ...	81·6	April 14 ...	77·6	April 18 ...	65·5
" 11 ...	78·0	" 15 ...	79·7	" 19 ...	66·9
" 12 ...	81·7	" 16 ...	75·2	" 20 ...	69·0
" 13 ...	77·6	" 17 ...	73·4	" 22 ...	73·0

Here we have a variation between extremes during thirteen days of 16·2 per cent. with potassium cyanide, while with amalgamation there was a variation of but 2 per cent.

In the foregoing the question of treating argentiferous ores after roasting has not been considered, as it is at once evident that such an extensive reagent as potassium cyanide, easily and quickly decomposed by the many acid salts formed in a chloridizing roasting, could not replace any of the several economical methods now in use.

RESULTS of EXPERIMENTS made with Potassium Cyanide on Gold- and Silver-ores from Different Mines.

Name of Mine.	Assay-value.		Per Cent. of Value extracted.	
	Gold. Oz. per ton.	Silver. Oz. per ton.	Gold.	Silver.
Gregory, Colorado	0·800	1·4	90·0	3·0
De Lamar, Idaho	1·000	26·0	90·0	83·0
Revenue, Montana	1·350	4·0	94·0	52·0
Southern Cross, Montana	1·220	0·7	93·0	50·0
Chollar Potosi, Nevada	0·130	2·6	76·2	70·4
Minas Prietas, Mexico	0·277	9·7	85·6	30·4
Atlanta, Idaho	0·600	5·2	63·4	78·6
Cou, California, and Virginia, Nevada ...	2·260	108·6	38·8	49·8
Paradise Valley, Nevada	0·090	49·2	77·8	25·8
Custer Company, S. Dakota	1·950	...	21·0	...

The experiments on the Gregory concentrates, which consist of pyrite, some arsenopyrite and chalcopyrite, with traces of galena and blende, were made by the Gold- and Silver-Extraction Company of Denver, Colorado. These pyrites are usually bought by the Boston and Colorado Smelting Company, which treats them, when mixed with other ores, by matte fusion, modified Ziervogel process, for the extraction of the silver, and a process of its own for the treatment of the rich auriferous bottoms. The De Lamar ore consists of a siliceous and limestone gangue, impregnated with silver sulphides and chlorides and pyrites. Some of the gold is free, but the greater part is in combination. The ores are at present treated by raw pan-amalgamation, which saves from 83 per cent. to 85 per cent. of the contents, and is considered satisfactory. A considerable quantity of this ore has been treated by the cyanide process with flattering results.

The ores from the Revenue Mine, Madison County, Montana, have puzzled metallurgists for many years. They are oxidized surface-ores, containing a considerable quantity of iron. When the mine was bonded to George D. Roberts, of New York, considerable attention was paid to the treatment of the ore by the late E. U. Riotte, who, after making various experiments, tried cyanide. His results were far from satisfactory, although it is now stated by Mr. Turner, the manager of the property, that they are extracting by the same process of cyanide some 85 per cent. It is also stated that 70 per cent. of the contents of tailings from amalgamation has been extracted at a cost per ton for extraction of £1; but, as the ore is one which would naturally cause a considerable consumption of cyanide, this statement seems doubtful. The Southern Cross Mine, of Deer Lodge County, Montana, has ores which contain from 42 per cent. to 50 per cent. of iron, in the form of limonite, evidently the result of the decomposition of pyrite. The ores have been treated in a ten-stamp gold-mill with amalgamated silver plates and with copper plates, but without extracting over 40 per cent. The gold is so fine that a speck can rarely be seen on panning large samples. The ore assays from £2 to £8 per ton in gold, with but a trace of silver, and its average value may be taken at £3 per ton. In 1890 a number of experiments were made on the ore by the cyanide process with good results, so far as extraction went; also experiments by the chlorination process, applied to raw ore. These were the first successful experiments by this process, as far as has been learned, applied directly to ores without undergoing a previous treatment. When leached by cyanide as much as 93 per cent. was extracted, the results on high-grade ore varying from that figure to 85 per cent. It was observed on treating in a rotating barrel that, whilst in a short time a large percentage of the gold was extracted, the quantity gradually decreased as the time lengthened, so that the results after a number of hours showed an extraction of only 25 per cent. This indicates that the ore either exerts a decomposing action on the solution or else precipitation occurs. It has been stated that experiments made recently on a large scale have proved successful, but in any event the consumption of cyanide would be large, and would increase with the extraction of less decomposed ore. Chlorination yielded on an average some 90 per cent., with a consumption of 10lb. of bleaching-powder and 15lb. of sulphuric acid to the ton. The total expense of treatment by this method would probably fall below 16s. per ton, if a sufficient quantity of ore were treated. The cyanide process, owing to the decomposition of the solution, would cost over £1 per ton.

The Chollar Potosi ores have been considered the most rebellious of the Comstock ores, not over 75 per cent., on an average, being saved by pan-amalgamation. From the tailings, however, cyanide extracts some 76 per cent. of the gold, and it is probable that the portion previously extracted by amalgamation would be extracted also, which would make a total extraction of 90 per cent. by cyanide.

The Consolidated California-Virginia ore contains metallic gold and silver and comparatively rebellious sulphides, such as tetrahedrite, stephanite, and sternbergite. The results, therefore, on both metals were low, but it is probable that the ordinary type of Comstock ore will yield far better results. Nevertheless, considering the perfection which pan-amalgamation has reached, it is extremely doubtful if the cyanide process will ever be introduced under the present management.

The ores of the Minas Prietas Mine, of Sonora, Mexico, consist of quartz, with oxides of iron and manganese, and hardly a trace of sulphur. Some of the gold is free, but the silver is more or less rebellious. The following results of the monthly runs of the 40-stamp Boss process, con-

tinuous, will be of considerable interest, as these tailings, amounting to nearly 100,000 tons, are now to be treated by the cyanide process:—

Value of Ore per Ton.		Value of Tailings per Ton.		Per Cent. extracted.		Value of Ore per Ton.		Value of Tailings per Ton.		Per Cent. extracted.	
Gold.	Silver.	Gold.	Silver.	Gold.	Silver.	Gold.	Silver.	Gold.	Silver.	Gold.	Silver.
$	$	$	$			$	$	$	$		
16·15	14·13	3·46	13·18	78·5	9·2	18·99	17·53	4·65	16·05	75·4	9·2
14·54	13·46	3·47	12·17	76·1	9·2	18·16	16·97	4·05	15·73	77·6	9·2
18·67	15·26	4·87	13·96	70·9	9·2	17·42	17·08	4·52	15·88	74·1	9·2
19·72	17·93	5·08	15·82	74·1	9·2	17·19	19·02	3·91	18·41	77·2	9·2

The higher-grade tailings have been worked with much success by the amalgamation process invented by Alexis Janier, but the low-grade tailings are left for the cyanide process; with this the extraction of gold will, undoubtedly, be very fair, and the consumption of cyanide low, while the silver will still remain rebellious. Considering the small contents of precious metals, it is doubtful if the process will prove a financial success. The Atlanta were extremely rebellious. They were treated, while the mine was in operation, by roasting in a Bruckner furnace, and were then amalgamated. The percentage extracted, however, was low, not running above 80 per cent. on the average, and with a heavy loss of gold in the furnace. The extraction by cyanide, all things considered, was quite fair, especially with the free surface-ores. Samples of tailings yielded nearly 80 per cent. of the gold and 60 per cent. of the silver contained.

The Paradise Valley ores are extremely good for experimental purposes, as they consist of a clean quartz gangue, with the mineral in the form of proustite and pyrargyrite distributed throughout it, so that the solutions employed act on the minerals alone, being entirely unaffected by the gangue. The results obtained in the extraction of gold by cyanide were fair, although there is but a small percentage in the ore, and that contained in mispickel. It is said that attempts are now being made to treat the tailings from the old twenty-stamp dry-crushing and chloridizing mill by the cyanide process.

The Custer County, Dakota, ore, which was tested by Mr. S. D. Porter, consisted of crystalline quartz with free gold, oxide of iron, and a small quantity of tellurium. By free milling 26 per cent. was extracted; and by concentrating 14·7 tons into 1 ton a concentrate valued at £47 18s. a ton was produced—a saving of 41 per cent. of the assay-value. Further tests, by concentrating 7·35 tons into 1, gave a concentrate valued at £33 1s. a ton, a saving of 57 per cent. Raw chlorination saved 84 per cent. Other ore in the vicinity gave results as high as 92 per cent. by the cyanide process.

E. N. Riotte made a series of experiments on the Bald Mountain ores by the cyanide process, but the results were not successful. Tests at the Golden Reward Works, Deadwood, where they are now using the barrel chlorination process with great success, were failures, according to the superintendent, Mr. Bamberger. Messrs. Frank and Darling have informed the writer that these experiments were successful so far as the extraction of the metals was concerned, but were failures mechanically, owing to the leakage of the vats. They state that 94 per cent. of the gold was extracted, and 87 per cent. of the silver, with a consumption of 0·9lb. of cyanide per ton.

Conclusions and Deductions.—It would seem probable that in ores containing both gold and silver only the oxidized surface-ores can be treated with success, both the silver and gold minerals from depth proving refractory. The Comstock ores give fair results, as should those of the De Lamar Mine, and the Minas Prietas ore should yield a high percentage of the gold, but very little of the silver. With the majority of these ores the consumption of cyanide would be large, as many minerals other than those of silver are contained in them, and would have a decomposing action upon the solution.

The interest which has been caused recently by the statement, substantiated by the fact, that cyanide of potassium dissolves the gold from auriferous pyrite and arsenopyrite, leaving the mineral to all appearances untouched and undecomposed, has reopened a much discussed question—namely, "the condition of gold in pyrite." These results, it is true, do not fully answer this question, for if the gold were either a sulphide, as it is claimed by some, or in the metallic state, the cyanide solution would still dissolve it; but, since the material operated upon is comparatively coarse, these results may give us some information as to whether the gold is in uniform mixture with the molecules of the pyrite, or simply a superficial and local deposition.

Those who have held the theory of chemical combination of the gold, silver, and iron in a double sulphide of the metals—and they number among them many eminent men—have based their arguments, as a rule, upon the difficulty of amalgamating the gold in these minerals when undecomposed, and upon the ease with which they are treated when the sulphur is eliminated, leaving, according to their theory, and in apparent confirmation of it, the gold in the metallic state. As the artificial sulphide of gold is unstable and is quickly decomposed by heat, leaving metallic gold, they argue that the gold in pyrite must have been partly at least in the form of a sulphide.

Others have subjected auriferous ores in which they suspected the existence of auric sulphide to the action of alkaline sulphides, claiming that if gold went into solution it existed as a sulphide, but forgetting that metallic gold is soluble in alkaline sulphides to a marked degree. In reality

those who believe in the occurrence of auric sulphides have relied chiefly for proof on the refusal of gold in pyrite to amalgamate readily, and this proof is open to many objections. The physical condition of the gangue—crushed pyrite in this case—might offer such difficulties as Malaguti and Durocher found with clay in the amalgamation of silver, or as are found at the present time in actual practice in treating chloritic and argillaceous ores by amalgamation. Little is known of the chemical or mechanical effect of gangue minerals on the affinity of mercury for gold or silver. Again, the gold while metallic might have been in an allotropic state analogous to that of silver found unamalgamable by M. Carey Lea. It might be coated by a film usually considered as iron-oxide, but more probably caused by the evolution of sulphuretted hydrogen from the decomposition of pyrite or marcasite. In any event this failure to amalgamate might be charged to many causes other than the presence of auric sulphide.

Ott, Wurtz, Bergman, Blake, and others, claim that metallic gold is disseminated mechanically through the mass of pyrite; but the action of cyanide of potassium and other chemicals on comparatively coarse material would seem to indicate that the interior of the crystals is not auriferous to any extent, and that, therefore, the deposition of gold must be superficial. The enrichment of the pyrite must be confined to its crystalline faces, and possibly, but not probably, to its cleavage-planes. The crushing by rolls or stamps of ore through which pyrite is disseminated does not reduce all the crystals of that mineral to powder, but liberates a portion of them from the gangue practically whole. A microscopical examination of the pulp will show this. Yet from these crystals, when concentrated, cyanide of potassium frequently extracts experimentally over 90 per cent. of the gold, and barrel chlorination, as proved by John E. Rothwell in actual practice, extracts, with or without the use of an oxidizing agent, such as nitre cake, an almost equal percentage. Certainly these results could not have been obtained where the gold disseminated throughout the crystalline mass. In the Republic of Colombia the writer found crystals of pyrite in a porphyritic gangue, which had, in many cases, gold in small globules on the surface, and also one octahedral crystal of hæmatite, evidently a pseudomorph after pyrite, weighing 638·7 milligrammes, and which had a globule of gold weighing 26·8 milligrammes on its surface. The crystal of hæmatite, after the large piece of gold had been removed, was shown to contain but 4·3 milligrammes of gold; and this, in all probability, was on the surface, in such small particles as to be invisible to the unaided eye.

Crystals of pyrite are not unfrequently found adhering to an amalgamated copper plate. This is undoubtedly due to the amalgamation of the particles of gold on their surfaces.

The ores of the Southern Cross Mine, Deer Lodge County, Montana, which consist of limonite from the alteration of pyrite amalgamated to about 40 per cent. In panning large samples but a colour or two of gold could be seen, although the ores assayed at times as high as £8 to the ton. From this ore over 90 per cent. of the gold was extracted in experimental tests by the use of cyanide of potassium, and fully as good results were obtained by chlorination in a closed vessel with bleaching-powder and sulphuric acid. Here the ore was thoroughly decomposed, but still the gold would not amalgamate to a much higher percentage than if it had existed with the original pyrite, while the chemicals took it immediately into solution. It will be seen that my main reasons for suspecting the gold to be deposited superficially and in the metallic state are derived from the actions of the several chemicals on unfractured pyrite; and the conclusions drawn from these results, while still somewhat hypothetical, are certainly more logical than those which have been evolved up to the present time. They may be summed up as follows:—

1. The gold exists in pyrite as metallic gold, not as a sulphide.

2. In the majority of cases the gold is confined to the surface of the mineral, and is not disseminated throughout the mass.

In connection with the foregoing, the following details of a microscopical examination, by Professor Marton, of the condition in which the pyrite was left after being leached with cyanide will prove interesting, as it confirms to a certain degree the theory advanced by the writer:—

"Upon the ordinary auriferous sulphide of iron, or arsenical pyrites, the solution of potassium cyanide acts readily, not by dissolving the sulphuret but by attacking the gold upon its exposed edges and eating its way into the cubes by a slow advance, dissolving out the gold as it goes. An examination with the microscope of the pyrite after the gold has been removed suggests the method of the operation. A sample of very rich sulphurets from a mine north of Reading was treated with a weak solution, less than two-tenths of 1 per cent., for 168 hours: the assay showed a complete extraction of the gold. As the sulphurets showed no change in their appearance to the naked eye, some of them were placed under the microscope.

"There is no change visible in the form of the crystals as a whole. Along the fractured faces the mispeckel looks clean and unaltered, showing the silvery-white colour and intense refraction of the arsenopyrite. Upon faces of the crystals appear dark lines, short and parallel to each other. In places they are crowded close together, in other parts they are at considerabie distances, but always in parallel lines. The lines vary in length, being from four to five times to over one hundred times their width. The lines are very regular, and often broken. These lines are fissures in the pyrites, and extend so deep into the pyrites that the microscope does not reveal their depth. By using the higher powers the walls of one of the fissures were seen to be completely honeycombed, looking somewhat like two empty honeycombs set opposite each other. Evidently the mineral removed was crystallized—along its contact walls, at least. As the raw or untreated pyrite does not show any such fissuring, but, upon the contrary, shows a surface marked only by striation lines common to pyrite, it is assumed that fissuring in the treated sample is caused by the solution acting upon some soluble mineral, probably gold, arranged in plates occurring in groups, but which, by its colour and isomorphism, and the extreme tenuity of its lines, is undistinguishable from the mass of pyrite enclosing it."

RESULTS of EXPERIMENTS with Potassium Cyanide upon Pyritic Gold-ores.

Name of Mine.	Assay-value.		Per Cent. extracted.	
	Gold. Oz. per ton.	Silver. Oz. per ton.	Gold.	Silver.
Oregon, pyrites	18·825	15·3	28·9	26·7
Murchie, pyrites	6·730	24·6	83·4	22·7
Calaveras, pyrites	5·925	32·0	94·8	68·6
Shasta, pyrites	15·260	11·8	80·5	84·5
Alaska, pyrites	2·110	0·5	82·0	84·48
Terror, pyrites	0·440	5·7	63·6	6·7
Boulder, ore	0·600	Trace	79·4	...
Plymouth, consolidated pyrites... ...	6·875	...	87·5	...
Plymouth, consolidated pyrites (wasted)...	11·250	...	93·8	...
North Carolina, pyritic ore	0·723	...	68·0	...
North Carolina, pyritic ore	4·500	...	90·0	...
Zinc-blende concentrates	1·560	...	84·0	...

The experiments on the Oregon pyrites were conducted by Mr. C. W. Merrill, and, as will be seen, were a failure. This ore yielded 90 per cent. by chlorination of the roasted ore. A partial analysis of it was as follows:—

SiO_2	23·109
Fe	36·590
S	33·620
Arsenic	6·304
Sb	0·522
Total	100·125

By amalgamation the ore yielded nothing. After deflagration with bicarbonate of soda and decomposition by acid the residue under a powerful microscope showed no gold whatever.

Mr. Merrill believes the poor results with this ore to be due to the gold being completely surrounded by the particles of mineral, so that it did not come in contact with the solution. Four solutions of different strengths were tried on another sample of this ore, with the following percentage-results:—

Strength of Solution.	Gold extracted.	Silver extracted.
0·12 ...	9·1 ...	10·5
0·25 ...	17·1 ...	19·4
0·5 ...	13·5 ...	14·2
1·0 ...	10·97 ...	14·0

This indicates that an increase of strength beyond 0·5 per cent. has apparently no beneficial effect. The pyrites from the Murchis mine are considered the most rebellious of California pyritic ores. When treated by the chlorination process an attempt to extract a portion of the silver by adding salt on the last hearth of a reverberatory furnace resulted in a large loss of the gold by volatilisation. The gold extracted by chlorination was about 85 per cent. of that remaining in the roasted ore, while subsequent lixiviation with calcium hyposulphide extracted only 25 per cent. of the silver together with a little more of the gold.

Considering the character of the ore, which contained a considerable percentage of arsenical pyrites, the extraction by cyanide was good. And if this result, notwithstanding the low extraction of silver, could be maintained this process would be more profitable than the chlorination process formerly used. The cost, unless the pyrites had become oxidized by exposure to moisture and the atmosphere, would be considerably less than for chlorination.

The experiments on the Calaveras pyrites were made by Mr. C. W. Merrill. The ore was nearly pure silica and pyrite, and by raw amalgamation yielded about 4 per cent. of its contents. After deflagration with bicarbonate of soda and treatment with acid coarse gold was observed under the microscope. The following results were obtained by use of cyanide solutions of varying strengths:—

Strength of Solution.	Gold extracted.	Silver extracted.
0·25 ...	51·4 ...	20·2
0·50 ...	65·8 ...	19·1
1·00 ...	87·4 ...	24·8

The table shows that increasing the strength of the solution had marked beneficial results. Mr. Merrill believes this was due to the accessibility of the gold to the solution. The result, 94·8 per cent., was obtained after two treatments, the first yielding 86·16 per cent. of gold and 45·13 per cent. of silver.

The Shasta and Alaska pyrites were of the common type, and the results were fair. The Boulder ore was arsenical iron-pyrites. The cost of treating this ore was stated by the Gold- and Silver-Extraction Company to be 10s. a ton, not including crushing.

The Plymouth consolidated pyrites were concentrates consisting of iron-pyrites with a small proportion of galena, and were treated by roasting in a reverberatory furnace 84ft. long, and

subsequent chlorination. The cost by this process was £1 14s. a ton; and the average result from January 15, 1884, to April 15, 1885, was an extraction of 95·23 per cent. These concentrates varied in value from £21 12s. to £30 a ton before roasting, and from £29 4s. to £41 8s. a ton after roasting. The treatment of these pyrites raw, thus saving roasting-expenses amounting to £1 3s. a ton, would hardly be profitable, for between £1 16s. and £2 8s. per ton more than by chlorination would be lost in the tailings, and in all probability the consumption of cyanide would be large, owing to the presence of sulphates. No saving would be effected by treating the ores by cyanide after roasting, since chlorination then costs but 15s. per ton.

The North Carolina pyrites were experimented upon by R. M. Eames and Son. The ore was iron-pyrites disseminated through slate rock. The solution was comparatively strong, 2 per cent., and the time five days. Another sample of ore was treated which analysed as follows:—

Silica ...	60·30
Alumina	9·00
Iron ...	12·00
Copper	6·00
Sulphur	9·50
Magnesia	2·00
Lead, manganese, and lime	Traces.

The results on this ore, which assayed 3oz. of gold to the ton, were very poor, the extraction being but 5 per cent.

The zinc-blende concentrates were treated by Mr. C. W. Merrill. An analysis of this ore was as follows:—

	Per Cent.
Silica ...	49·31
Sulphide of copper	0·18
Pyrite...	6·43
Galena	6·39
Blende	37·69
Total	100·00

This ore yielded 33 per cent. of its gold by free amalgamation. After deflagration with bicarbonate of soda, leaching with water, and decomposition by acid, the residue showed a nugget of free gold.

Mr. Merrill ascribes the poor results on this ore to the great affinity of zinc for cyanogen, which rendered inert the affinity of cyanogen for gold; but the good results obtained from the Black Jack concentrates of the Ravenswood Mine, Queensland, which are now treated by chlorination, show that this theory is probably erroneous. The interference of this mineral cannot be considered proved as yet. In all probability it was the presence of iron salts, not showing by acid reaction, which caused the difficulty.

Experiments were made by the State Mining Bureau of California on pyrites typical of those reduced in the chlorination-works at Sutter Creek (Cal.), and assaying 5·1oz. of gold per ton. The following results, showing the effect of time on the efficiency of cyanide, were obtained with a 1-per-cent. solution:—

Time in Hours.	Extraction per Cent.
2	64·71
3	68·63
4	69·63
6	74·51
8	78·44

The sulphurets in physical condition were as fine as those treated by chlorination.

After grinding the ore through a 100-mesh screen, 82·36 per cent. of the gold was extracted; and after grinding in an agate mortar and digesting with three different solutions of cyanide, the extraction was 90·2 per cent. A second lot of sulphurets, ground through a 120-mesh screen, yielded 90·6 per cent. of their gold after eight hours' digestion with a 1-per-cent. solution.

Conclusions and Deductions.—It will be seen that many favourable results have been obtained by the experimental treatment of pyritic ore; but it must be remembered that in these tests, with large excesses of chemicals, the important factor of cost does not enter. This cost, as will be explained in another place, does not arise from mechanical difficulties, but is owing to chemical troubles, due almost solely to the decomposition of the solution by salts which are always present in partially-decomposed pyritic ore. It may be, and probably is, quite possible to neutralise these salts by alkalies, but even then the cost will be high, for the excess of chemicals, which must be used, has a tendency to increase the consumption of cyanide and of zinc in the precipitating bases.

In South Africa no success has been obtained as yet with this class of ore, and it seems more than doubtful if it ever will be. The field in this country is still open, however, to intelligent work in this direction. To effect economical and successful working, the constituents of the ore must be known, and their variations in composition discovered in time to modify the treatment so as to secure the best results.

The Plant.

It has been stated that the cyanide process is so simple that the plant may consist of old barrels or tanks, placed together in any way, with crushing machinery of any description. The absurdity of such a statement is apparent to the metallurgists, but not always to the miner. The process is not complicated, it is true, but it is far from being simple, and a proper arrangement of the plant not only increases the percentage of extraction and the capacity of a mill, but reduces work-

ing-expenses. With low-grade ores financial success is often due to the perfect mechanical arrangement of the metallurgical plant. Before discussing the plant in detail, it will be well to consider the comparative merits of rolls and stamps, and of wet or dry crushing in preparing ore for lixiviation.

The Advantage of Dry Crushing by Rolls.—Where the ore is to be leached raw, without roasting, rolls possess many advantages over stamps beside the very decided one of the first cost. First, the uneven product of the stamps and the large percentage of dust and slimes cause the ore to leach slowly. As the number of tanks used for lixiviation depends upon the leaching-rate, this increases the number of tanks required, and, consequently, both the first cost and the operating-expenses.

So much is the leaching of raw ores delayed by fineness that at Silver City, New Mexico, where the tailings from the Bremen mill, ground fine in pan-amalgamation, were leached by the Russell hyposulphite process, the rate of leaching, although aided by the use of pumps to exhaust the air from the bottom of the tank, fell as low as $\frac{1}{16}$in. per hour. The rate for raw ores crushed through a twenty-mesh screen by rolls would be at least 6in. per hour, and probably more.

Dry crushing by rolls is also preferable for other reasons. If ore is crushed wet, it must be run in settling-tanks, or else directly into the lixiviation-tanks. If it is run into settling-tanks, extra handling is necessitated, and in either case the ore is deposited in layers, according to the size and specific gravities of its constituents. The heavier and more rebellious minerals fall to the bottom, and the lighter particles, settling last, form a coating almost impervious to the solution. It is true that a partial mixture is effected when the ore is shovelled into the tanks; but it is partial only, and the slimes, which do not mix with the other ore, render leaching difficult. This difficulty also occurs in agitation, the method first proposed for treating ores by the cyanide solution. If the ore is agitated with the solution, and finally allowed to settle, the supernatant liquid can be recovered, and the metals precipitated; but that remaining in the ore—say, 500lb. to the ton—containing not only its *pro ratâ* proportion of the precious metals, but some 5lb. of cyanide to the ton of ore, if a 1-per-cent. solution is used, costing some 10s., cannot be recovered without greatly diluting the solution, and then but partially. It is for this reason that agitation has been generally abandoned for the process of lixiviation.

The delivery of the ore to the lixiviation-tanks is equally simple when either wet crushing or dry crushing is used, but it is more expensive when settling-tanks are employed intermediately.

As, however, the direct discharge of the ore to the tanks from the stamps is impracticable, the uneconomical settling-tanks must be used. It is to be admitted that the cost of wet crushing by stamps is less than that of dry crushing by the same means, as the capacity wet is nearly double that dry, the same power being employed in each case; but the lesser cost of rolls, both as to purchase and operation, is so much in their favour that, aside from the indisputable fitness of their product for lixiviation, they must be universally adopted. In fact, rolls are equally well adapted for lixiviation and concentration, as in both processes evenness of product is essential to good work.

A plant for the treatment of ores by the cyanide process differs in a few details from that of any hydro-metallurgical process for unroasted gold- or silver-ores. It consists, in brief, of driers for the ore, crushing-appliances, conveying apparatus, tanks for lixiviating the crushed ore, and for the solution troughs in which the metals are precipitated, conveniences for the precipitation, and the usual minor details necessary to an economical metallurgical plant.

Driers.—The driers commonly used in dry-crushing silver-mills are the common unlined rotary iron drier, which has been within until a few years almost universally used, and the Stetefeldt dry kiln, a modification for this purpose of the Hansclever furnace. The rotary drier has the merit of low first cost, but the Stetefeldt kiln is cheaper to operate. The Stetefeldt kiln has also the additional advantages of occupying less space and having a greater capacity than the rotary drier, which are no slight merits when grading has to be done. Again, the hottest gases in the Stetefeldt kiln are utilised in drying the wettest portion of the ore, while the reverse of this is the case in the rotary drier. The capacity of the rotary drier is, however, more than doubled by the simple device, introduced by R. P. Rothwell, of dividing the cylinder longitudinally by iron, or in a roasting-furnace by tile, diaphragms, into three or more compartments, thus dividing the ore and bringing it up into the hot portion of the cylinder, and turning it over more often. A cylinder of this kind was first used at Deloro, Ontario, Canada, and one is now in use at the chlorination-works, Deadwood, S.D.

Further crushing of the ore broken by the rock-breaker is done in ordinary rolls, crushing to about six-millimetre size, as should be used in the coarse crushing of a concentration plant. The product of these rolls should pass through a double trommel—one a screen having six-millimetre meshes, and the other being sufficiently fine—say, one millimetre—to permit the ore passing it to be taken directly to the leaching-tanks, while the portion remaining behind in the last screen is sent to the rolls or stamps for recrushing. The proportion of the ore which may be passed directly from the roughing-rolls to the leaching-tanks depends upon its friability, and may amount to from 15 to 25 per cent. of the whole. That portion of the ore rejected by the six-millimetre screen is returned to the roughing-rolls. As the ore is crushed dry, the rolls and trommels must be housed and provided with suitable dust-chambers. Only a small quantity of dust is made, however, and this may be mixed with the ore from the final crushing, when its effect upon filtration will be slight.

Conveyors.—If this important portion of the plant is properly arranged, the ore need be handled but once after leaving the drier. Between the rock-breaker and the drier, if rotary driers are used, there is no conveyance except by gravity, but if the Shelf dry kiln is adopted the broken ore must be elevated in cars to the top of the kiln. This may be obviated, if there is sufficient grade, by placing the top of the kiln below the level of the breaker, or, preferably, by having the crusher at the ore-bins, and taking the broken ore in tramcars to the top of the dry kiln.

The dried ore from the kiln falls into cars which are wheeled to the rolls and discharged into hoppers. Between the rolls and the trommels there are bucket-elevators. The ore passing over the six-millimetre screen falls back through a chute, either to the hoppers or to the rolls direct, the

first method being preferable, as the feeding and the wear of the rolls are then uniform. In the same way, the ore refusing to pass through the one-millimetre screen is conveyed through a chute to the finishing-rolls, while the fine ore passing the screen falls into a trough in which there is a screw conveyor. The product from the finishing-rolls is elevated to another one-millimetre trommel, from which the coarser portion is returned by the chute to the rolls. The finer portion passing the screen falls into the screw conveyor mentioned before, which moves it to either side of the mill. The conveyor shaft and box are placed, if possible, between, and slightly above, the two parallel rows of leaching-tanks running transversely across the mill. There is a slide in the bottom of the conveyor-trough, which can be opened to allow the ore to fall into a chute which reaches nearly to the bottom of the tank. This chute is made of canvas, and widens gradually toward the bottom. Its outlet is kept open by an iron ring, the weight of which holds it in position, which is changed from time to time by the man in charge of the tanks.

As the tank fills, the feeding is directed towards the sides, and the ore spread out evenly. The charging of the tanks is almost automatic, and requires but little attention. The particulars of this conveying system will, of course, vary somewhat with the capacity of the plant, but for a plant of, say, 40 tons daily capacity the plan would be substantially as described.

Leaching-tanks.—The number and size of the leaching-tanks depend upon the capacity of the mill, and the time required to treat the ore. Generally the tanks should be charged in every shift of either eight or twelve hours. The capacity of each tank would, therefore, be either one-half or one-third the daily capacity of the mill, and the number of tanks either twice or three times the number of days required to fill and leach a tank, with one or two additional, so that at least one tank may always be empty.

The tanks for the cyanide process do not differ materially from those for any other of the lixiviation processes. They are generally constructed of wood, and are cylindrical in form, although iron tanks and rectangular wooden tanks have also been used in this country.

The objections to the use of iron tanks are that they are fully as expensive as wooden tanks, are difficult to calk if they leak, and are easily corroded by the solution and the moisture. Rectangular wooden tanks are less expensive than cylindrical tanks of the same material, but it is very difficult to keep them from leaking.

The tanks should be constructed of well-seasoned lumber, with staves from 3in. to 4in. thick, having their inner and outer faces cut to correspond to the arc of circle of the tank, and their edges radial to this circle. The staves should be at least 1ft. longer than the inside depth of the tank, and gained from 1in. to 1½in. into the bottom timbers, with a chime of several inches. The bottom should be of heavier timber than the sides, tongued and grooved, and put together with white-lead or litharge and glycerine. Those who have worked in a mill with leaking tanks, improperly constructed, know how necessary this latter precaution is. The hoops should be made of wrought-iron rods from ¾in. to 1½in. in diameter, according to the size of the tank, with threaded ends passing through wrought-iron lugs, and tightened by hexagonal nuts. The framework upon which the tanks rest should be built of strong timbers, and should be sufficiently high to allow easy access to the bottom of the tanks. When the tanks are of large diameter these hoops are made in sections.

The tanks, when finished, should be painted with paraffine paint, or a mixture of asphaltum and coal-tar. The use of white-lead, except in forming the bottom where it is not exposed to the action of the solution, must be avoided. The filters are usually constructed of wooden slats supporting a burlap filter. Perforated slate slabs have been proposed, and it would seem advantageous to use them, or else perforated porcelain tiles, as in tanks for the filtration of the gold solution from the ore in the modern chlorination process. The tiles do not absorb gold as does the wood. The slats are usually 2in. high and 1in. wide, and are fastened to the bottom 1in. or less apart. This should be done with wooden pins. Grooves ¾in. deep and at least 3in. wide are cut in a number of places in the bottom, to allow the free passage of the solution along the bottom. Between the ends of the slats and the inside of the tank an annular space about 1½in. wide is left, which is partly filled by a strip of wood 1in. thick, bent to the circle of the tank. Over this and the slats the burlap is spread and held by a rope ½in. in diameter, which is driven into the space remaining between the strip of wood and the staves of the tank.

The discharge-pipe is made of heavy six-ply rubber hose, 2in. in diameter, inserted into a tank through a 3in. plank fastened by screws to its bottom. The hole for the hose is bored at an angle of 30°, and ends at the centre of the tank. The joints are made with white lead, and the hose is fastened to the tank by wooden pins. The hose discharges into an asphalt-coated launder, which leads to the zinc-precipitation boxes or to another tank.

The tailings in a well-constructed mill should be sluiced out of the tanks by water under a slight pressure. This materially reduces the cost of discharging the tanks. The sluice-gate is from 18in. to 28in. wide, and 8in. high. The door is covered with a strip of blanket or rubber. For the large tanks there should be two of these placed opposite each other. The bottom of the gate is flush with the surface of the filter.

The size of the tanks depends upon the capacity of the mill and the rate of leaching. An increase in diameter increases the amount of ore leached per charge; but an increase in depth does not. The weight of a cubic foot of dry-crushed ore varies from 75lb. to 110lb., depending upon the mineral constituents and the fineness of the grains. The weight per cubic foot being determined, it is a simple matter to calculate the size of the tanks to be used. It is rarely convenient, except where very large charges are treated, as at the tailings-mills in South Africa, to make the net inside depth of the tanks over 60in. A tank with this depth and a diameter of 20ft. contains nearly 100 tons of an average ore, and a tank 14ft. in diameter and of the same depth contains about 50 tons. It is much better where room is plentiful to increase the diameter than to increase the depth of the tanks.

The pipes leading to the tanks should be about 2in. in diameter, and three in number for each tank—one for the cyanide solution, another for the wash-water, and a third for the caustic-alkali solution, in case it is used. These should be placed at the sides of the tanks, just above their edges. The cocks and valves should be of iron, although on the wash-water pipes cocks of any metal may be used.

Solution-tanks.—The tanks for the cyanide solution are constructed substantially the same as the leaching-tanks, with the exception of the filter. They are frequently placed below the level of the floor, but this arrangement is undesirable, as repairs cannot be easily made. Their number and capacity depend entirely upon the strength of the solution and the capacity of the mill, and whether the circulation method is used. This method reduces the quantity of solution required, but has its drawbacks, which are explained elsewhere. In general it may be said that a mill of 100 tons daily capacity, using a 0·8 per cent. solution, and working on ore carrying ½oz. of gold to the ton, requires 100 tons, or about 3,000 cubic feet, of solution for actual leaching purposes. In addition to this, however, there should be a surplus of not less than 50 per cent., which would increase the necessary capacity of the storage tanks to 4,500 cubic feet.

Dissolving-tank.—A tank constructed in the ordinary manner is needed in dissolving. The cyanide is dissolved more readily; there is less extra solution to handle. The operation of bringing the working-solution up to its normal strength is more easily effected, and the so-called carbide of iron, which commonly is an impurity of the commercial cyanide, is left in the tank and does not enter the working-solution. The strong solution, if impurities are present in large quantities, is siphoned from this tank into the storage tanks, but is ordinarily drawn off through a valve, the inlet of which is covered with iron- or steel-wire gauze.

A tank is also required, if the ore has an acid reaction, for the caustic-alkali solution. Enough of this solution must be used to saturate the ore, generally from 7 to 10 cubic feet per ton. The construction of this tank should be similar to that of other tanks.

Pumps and Pipes.—Several pumps are used to raise this solution from the sumps to the solution and lixiviation tanks, and to provide circulation if this process is used. They may be of ordinary construction, except that no part which comes into contact with the solution should be of brass. The pipes are of iron, and vary from 2in. to 3in. in diameter, the largest size being used to convey the water for sluicing.

Zinc-precipitating Boxes.—The zinc-precipitating boxes are usually constructed of wood, but it is well to use a less absorbent material. They are from 14ft. to 20ft. long, and about 2ft. deep, and are divided into compartments from 1½ft. to 2ft. long. These compartments are each filled with from 30lb. to 40lb. of zinc shavings, which rest on a tray, the bottom of which is an iron-wire sieve. The solution flows alternately upward and downward through these compartments. One compartment at the head is left empty to permit any impurity, such as sand, to settle. At the outlet end a double compartment is left open to catch the gold which may be mechanically carried by the solution. If both a weak solution and a strong solution are used in leaching, a double set of zinc boxes is employed.

Plant for treating the Precipitate.—The plant for treating the precipitate consists of furnaces over which the precipitate, freed from the greater portion of the zinc, is dried, and in which it is melted in black-lead crucibles. The ordinary wind bullion-melting furnace answers this purpose, but it should be constructed with dust- and fume-chambers, with alternate up- and down-takes, in order to collect as much as possible of the zinc oxide which is produced; otherwise, this and the considerable quantity of gold it contains is lost. In many cases, however, the zinc oxide has not commercial value, and is saved for the gold alone. A muffle furnace, in which a partial oxidation of the zinc is effected previous to melting, is also used in some localities. In this country it will be more profitable in most cases to sell the precipitate to smelters than to attempt to refine it.

The Assay Plant.—The assay office has the ordinary crucible and muffle furnaces, or a muffle of sufficient size to hold crucibles. These are for the assays of crude ore, tailings, and bullion. As the process is of a chemical nature, and subject to many puzzling changes in its operation, the assay department should have a competent chemist, and be provided with the apparatus necessary to determine the more common metals, and to test the strength of the solution and of the crude cyanide. This apparatus, with the necessary stock of chemicals, is not expensive, and should always be provided. Its use will help the process when successfully working, and when a failure is being made will frequently place the metallurgist upon the right track. The assay office is in reality the most important part of a cyanide plant, and its thorough equipment should not be neglected.

The Lixiviation of the Ore.

Wash-water.—When the ore reaches to within six inches of the top of the tank, wash-water, if the ore contains soluble salts, is allowed to fill the tank until the ore is slightly covered. Actual practice alone determines how long this water should be allowed to remain in contact with the ore, but in most cases a few hours are sufficient.

Treatment by Caustic Alkali.—If the ore requires subsequent neutralisation by caustic alkalies, the wash-water is run down to the surface of the ore, and then the alkaline solution is run on until the tank is filled. The solution is allowed to remain in contact with the ore for some time. Attempts have been made to do away with the use of this caustic solution by mixing lime with the ore, but it is readily seen that should an excess be added the consumption of cyanide will be increased, owing to the lime causing double decomposition with the carbonate of potassium always accompanying commercial cyanide of potassium, and forming insoluble carbonate of lime and caustic potash. The caustic potash causes an excessive consumption of zinc in the precipitation-boxes, and in addition very probably reacts on some of the metallic components of the ore-forming compounds which are dissolved by cynanide, and which cause a loss in its solvent action on the precious metals, besides producing a base precipitate if these metals are precipitated by zinc.

The Cyanide Solution.—The weak caustic-alkali solution is allowed to remain in contact with the ore the length of time found necessary, and when drawn down to the surface is followed by a charge of the strong working solution which replaces the alkali solution. The alkali solution is allowed to run away until it gives a reaction for cyanogen by any of the well-known tests, such as ferrous sulphate. The outlet is then stopped, and the cyanide solution allowed to fill the tank to a point just above the surface of the ore. This solution, like the preceding ones, remains in contact with the ore for at least twelve hours. The strength of the solution varies, according to the ore, from a fourth of 1 per cent. (5lb. of cyanide to the ton of water) to eight-tenths of 1 per cent. (16lb. of cyanide to the ton of water). The pressure or absence of base metals determines this point. In general, it may be said that an excess of cyanide above the amount which is found to work most advantageously is deleterious, as greater opportunity is given for the decomposition of the solution by the atmosphere and carbonic acid and for the extraction of base metals. After the necessary time has elapsed, this first solution, which carries the greater portion of the gold extracted, is allowed to flow away to the precipitation-boxes and is replaced by other solutions. This lixiviation is continued, according to the rebelliousness of the ore, from twelve to twenty-four hours, these being practically the extremes. To determine whether extraction is still going on, a sieveful of bright zinc shavings is exposed to the action of the solution. If the zinc is discoloured after an hour's time by metallic precipitates, leaching must be kept up until there is no such deposition. The rate of leaching depends entirely upon tho physical condition of the ore—the finer it is the slower the rate. It varies between 1in. per hour with fine material to 9in. per hour with coarse quartzose granules.

The Weak Solution.—The solution after leaving the zinc-boxes frequently contains an appreciable percentage of free and active cyanide of potassium. This is utilised by pumping it back into the ore after the first one or two charges of strong solution have gone through. The saving effected by this is considerable, as it lessens the amount of strong solution required over the consumption by decomposition.

If the weak solution is used the operation is continued as described, except that this solution, after leaving the tanks, is diverted to its own separate precipitation-boxes, where the precipitates formed are decidedly poorer.

Agitation of the Ore and Solution.—As this was the original method proposed, although it has been invariably unsuccessful wherever tried, it is still attracting some interest. There are, however, several objections to its use. First, the decomposition of the cyanide, exposed to the action of the atmosphere more than in the lixiviation system, is abnormally high; the tailings assay low, showing a large apparent extraction, but all of the gold cannot be recovered, as it is impossible to free the ore from solution after it is run into the leaching-tanks. The power required to stir a large quantity of ore is also considerable, being at least one-horse power per ton. The method has been attempted unsuccessfully with several wet processes, notably the Russell hyposulphite lixiviation process, at Bullionville, Nevada.

Circulation of the Solution.—This consists in pumping the solution flowing out of the tank back again without precipitating the gold already in solution. This method has been adopted at several South American works, but in the absence of any definite data upon the subject the financial success of the method is open to doubt, although, as stated before, it has several favourable features. Similarly, when circulation is used in the Russell hyposulphite process a precipitate is found on the top of the ore which contains considerable gold and is ultimately lost. The pumping heats the solution, causing more rapid decomposition and a greater solvent energy for the base metals. Lixiviation and precipitation with or without a return of the solution freed from its contents of precious metals must be considered the approved method.

Final Wash-water.—When it is found that the solution leaving the tanks no longer contains an appreciable amount of gold, the cyanide solution is allowed to rise to the surface of the tank, and wash-water in a sufficient quantity to displace the cyanide solution is added. Seven to nine cubic feet per ton, or from 437·5lb. to 562·5lb., is usually required. This fills the tank to a certain depth, known by experience. The outlet is then opened, and the solution allowed to flow to the zinc-boxes, until the wash-water has sunk to the surface of the ore, after which the water is allowed to run to waste. An appreciable loss of cyanide occurs here, which cannot be well avoided.

Sampling the Tailings and Ore.—Before the tanks are discharged samples of the tailings are taken for assay. This is usually done with a long-handled semi-cylindrical probe, which is driven to the bottom of the tank and then lifted out with the tailings adhering. Samples should be taken from different parts of each tank, and those from each tank, with the sample taken after the first wash-water and before the cyanide solution is run on, must be kept separate for a check on the working of each tank. The original value of the ore is determined from samples taken at the rolls.

It is well to often assay, separately, samples from the bottoms of the tanks and from the sides, to determine if the extraction has differed locally, for the solution in an improperly charged tank has a tendency to flow down the sides. This is remedied by tamping.

Discharging the Tailings.—In a mill constructed as before described the tailings are sluiced out by water under head, or by the pressure of a fire-pump should a natural head be wanting. The operation is simple and rapid. The sluice-gates are opened and the head of water partially turned on. The sluice-ways carrying the tailings must be large enough and have a sufficient fall to allow the stream to run rapidly away to the dump. If the tanks are discharged by hand the cost is much greater, being 5d. to 8d. per ton, while it is less than ½d. per ton where water under a head is abundant.

Precipitation of the Gold.—Since the cyanide process has been used on a large scale a number of precipitants are being tried, but, with the possible exception of the Malloy process, which will be spoken of later, the only one which was proved successful is metallic zinc in the form of shavings. Zinc dust precipitates the gold, but it is impermeable to the solution. Sheet zinc offers

too small a surface to the solution, and the same objection is open to granulated zinc. Sheet zinc, forming the poles of a galvanic battery, has been tried, it is said successfully, on an experimental scale. This is undoubtedly the weakest point of the cyanide process, and it is to be hoped that some means other than the present will be devised by which the bullion may be recovered in a purer state, and the solution be less affected.

The zinc shavings are prepared by turning in an ordinary lathe a cylindrical block, being made of a number of discs of sheet zinc placed on a spindle. The expense is considerable, two men being employed on this work constantly in works of large capacity. Nor can the prepared shavings be shipped, as not only would they be extremely bulky, but the bright surface would become oxidized, diminishing their efficiency for precipitation. These shavings are placed in the compartments of the precipitation-boxes already described. Those in the first few compartments are more vigorously attacked than elsewhere, as the greater portion of the gold is precipitated here. These compartments are therefore replenished from time to time with fresh shavings from the last compartment, where those directly from the lathe are placed.

The gold is precipitated as a blackish, or under certain conditions as a whitish, powder. To remove the gold precipitate, which is generally done every two weeks, the iron screen upon which the shavings rest is first lifted from the legs on which it rests. The finely-divided gold in the boxes is then allowed to settle for an hour or so, after which the supernatant liquor is syphoned off, without disturbing the precipitate. The boxes are then cleaned out and the slimes and water allowed to drain through a fine screen, and the gold and the fine zinc which remain in the screen rubbed through it by means of a stick with a piece of rubber fastened to its end. The remaining portion, consisting almost entirely of unconsumed zinc, is placed in the first zinc-boxes on top of a fresh lot of zinc shavings. The matter which has passed the screen, consisting of metallic gold and silver, metallic zinc, lead and tin derived from the zinc, some sand and organic matter, and a small amount of copper, is allowed to settle in the tank under the screen. It is then ready for drying and treatment for the production of bullion. It seems probable that much trouble could be avoided in the drying and melting, and in the treatment of precipitate by acid if used, by employing a filter-press such as Johnson's, which is used in the pressing of sulphides from the hyposulphite process. This press is simply and easily managed. The precipitate could be drawn by a vacuum from the tank into which the slimes are screened and forced by steam pressure into the press, and there subjected to a pressure which, although they would still contain a considerable quantity of water, would leave them in a more convenient form for subsequent treatment. They would then have to be dried and melted. After drying, however, they would be in a good condition for treatment by any of the proposed acid processes.

Treatment of the Auriferous Precipitate.—The slimes are transferred to enamelled iron pans and dried over a fire. This is a tedious operation, requiring considerable time and care. When dried the usual course is to transfer the precipitate, mixed with sand, borax, and bicarbonate of soda, to a graphite crucible, where it is melted little by little, more being added as the precipitate melts. When the pot is full it contains—at the Robinson works, where a No. 6 crucible is used—from 100oz. to 150oz. of bullion. As large quantities of zinc-oxide are given off in a melting, and carry off a considerable quantity of gold, the furnace should be provided with suitable dust- and fume-collecting chambers.

Various schemes have been devised to perfect this portion of the process. One method consists in roasting the slimes in a muffle furnace and volatilising a portion of the zinc as an oxide. These furnaces may be constructed like the Belgian zinc-distillation furnaces, the retorts being made of fire-clay, and a condenser and a sheet-iron drum being placed at the mouth to save the zinc-oxide and the gold which is volatilised. The bullion produced after following this process would be of considerably higher grade than that produced without a previous roasting, and is much less bulky. The bullion now made is of a whitish colour, and varies from 650 to 800 fine.

Sulphuric and hydrochloric acids have been tried for dissolving the zinc after the soluble cyanide salts had been leached out, but the difficulty of freeing the slimes from the soluble cyanides, and afterwards from the zinc-sulphate by filtration, prohibits their use. An acid sodium-sulphate may be used for dissolving the zinc, the reaction in this case being,—

$$2NaHSO_4 + Zn = ZnNa_2 2SO_4 + H_2$$

—leaving the gold, silver, and a portion of the other metals behind.

The Chemistry of the Process.

Solution of the Gold.—The solubility of gold in a solution of cyanide of potassium has long been known, as is shown in another section. Elssner claimed ("J. Pr. Chem.," xviii.) that the presence of oxygen is necessary for the reaction after the formula—

$$2Au + 4KCy + O + H_2O = 2KAuCy_2 + 2KHO.$$

That is, a double cyanide of gold and potassium is formed. This was proved by the formation, upon evaporating the solution, of octahedral crystals answering to the formula. To my mind, however, the necessity of oxygen has not been proved, and I consider that the following reactions are more correct:—

$$Au + 2KCy + H_2O = KAuCy_2 + KHO + H.$$

It certainly seems more logical that there should be a simple interchange between the gold and the potassium, forming metallic potassium, which is decomposed in the nascent state by the water of the solution, than that there should be another element necessary to the reaction. The theory of the second reaction is upheld by experiments, which showed that strongly concentrated solutions of potassium-cyanide have less solvent energy upon metallic silver than the weaker ones. This was supposed to be due to the polarising action of the hydrogen. In this case minute bubbles covering the

cement silver could readily be seen. Which of the two is the actual reaction plays but little part in the working of the process, however. There will be a few complaints of insufficiency of oxygen, as, according to the reaction, but 15·96 parts of oxygen by weight are required to dissolve 396·6 parts of gold. The probabilities are, however, if oxygen is required at all, that it must be present in larger quantities, as no hydro-metallurgical process works in practice in exact accordance with the simple chemical formula. If the cyanide process in particular did so, only 130·04 parts of cyanide of potassium would be lost in dissolving 106·8 parts of gold—or, more correctly, two parts of cyanide to three parts of gold; but in reality the quantity consumed amounts, on the freest ore, to 3lb. to the ounce of gold recovered, or 43·7 parts of cyanide to 1 of gold. On more refractory ores, containing soluble base metals, and particularly acid salts, the consumption is greatly in excess of this.

Solubility of other Metals and Minerals.—According to Guielin, zinc, iron, nickel, and copper are dissolved by potassium-cyanide, with evolution of hydrogen; cadmium and silver in the presence of oxygen; and tin, mercury, and platinum not at all. Sulphide of silver is dissolved by strong solutions and a sufficient quantity of weak solution. Silver-arsenate (Ag_3AsO_4) and silver-antimonate ($Ag_2Sb_2O_5$) are readily dissolved by potassium-cyanide, as are many of the argentiferous arsenical and antimonial minerals found in nature. Chloride of silver dissolves readily, forming chloride of the alkali and a double cyanide of silver and potassium. While metallic silver, when sufficiently fine, dissolves readily in the solution, that found native in ores is not attacked unless existing in their laminæ. The oxides and sulphides of copper are attacked by the solution, and dissolved, as is metallic copper. It is claimed that the presence of copper-sulphide in a silver- or gold-ore prevents the precious metals from going into solution. Although experiments have shown that little or no silver or gold is dissolved in certain ores containing sulphide of copper, this question is by no means settled, as artifically-prepared sulphide of silver is dissolved in actual contact with the copper compounds. Metallic iron is attacked, but very slowly. Ferric hydrate is not attacked by the solution, but ferrous hydrate formed in the neutralisation of the iron salts by alkali is attacked by cyanide, according to the reaction,—

$$Fe2HO + 6KCy = K_4FeCy_6 + 2KOH.$$

Thus ferrocyanide of potassium and caustic potash are formed.

Treatment of Pyritic Ore previcus to Lixiviation with Cyanide.—Pyritous ore, if but slightly exposed to atmospheric action, always contains free sulphuric acid and soluble salts of iron. To prevent reactions on the solutions, it is necessary to leach these ores with water previous to lixiviation with cyanide of potassium, and before washing with an alkali. If the alkali solution was added directly to the ore, the consumption of alkali would be extremely large, and the amount of solution necessary, if lime was used, would prove inconvenient to handle.

The alkali solution, assuming that caustic soda is used, reacts on basic iron salts, insoluble in water, according to the following reactions:—

$$Fe_2O_3, SO_3 + 2NaHO + 2H_2O = Fe_2(HO)_6 + Na_2SO_4; \text{ and}$$
$$Fe_2O_3, 2SO_3 + 4NaHO + H_2O = Fe_2(HO)_6 + 2Na_2SO.$$

Thus ferric hydrate and sodium-sulphate (or calcium-sulphate if lime is used) are formed. Sodium-sulphate is soluble, and passes off with the wash-water, but calcium-sulphate remains. The hydrate of the sesquioxide of iron is insoluble in water, and, to all appearances, is unattacked by the cyanide solution; but, as has been mentioned before, the hydrate of the protoxide is dissolved with formations of ferrocyanide of potassium. Mr. C. W. Merrell precipitated ferrous hydrate by caustic potash from a cyanide solution. The solution contained but a small percentage of free cyanide, as it had already acted on the ore and zinc in the precipitation of dissolved gold, and it is unlikely that this reaction, regenerating the cyanide of potassium, which had been rendered inert by the solution of the iron, would occur in a comparatively strong solution.

Direct Treatment of Pyritic Ores by Cyanide of Potassium.—As has been explained, the direct treatment of these ores is unadvisable and extremely expensive. Pyrite (FeS_2) is decomposed by the oxygen of the air and moisture into soluble ferrous sulphate and free monohydrated sulphuric acid; according to the reaction—

$$FeS_2 + H_2O + 7\,O = FeSO_4 + H_2SO_4.$$

The ferrous sulphate is decomposed by the action of the air to insoluble basic sulphates. In addition, normal ferric sulphate ($Fe_3\,3\,SO_4$) is produced, which gradually loses acid and becomes a soluble basic sulphate, $Fe_2O_3\,2\,SO_3$. There are many basic salts of somewhat complex and doubtful composition formed likewise. Thus, in an oxidized ore which has contained pyrite are found sulphuric acid, ferrous sulphate, basic ferric sulphates, ferric sulphates, and basic ferrous sulphates, all of which react upon potassium-cyanide. Sulphuric acid reacts upon potassium-cyanide with evolution of hydrocyanic acid, according to the reaction,—

$$2\,KCy + H_2SO_4 = K_2SO_4 + 2\,HCy.$$

Ferrous sulphates react upon cyanide with the formation of ferrous cyanide, a yellowish-red floculent precipitate:—

$$FeSO_4 + 2\,KCy = FeCy_2 + K_2SO_4.$$

This ferrous cyanide is attacked by the excess of the cyanide in the solution, and ferrocyanide of potassium is formed, according to the reaction,—

$$FeCy_2\,4\,KCy = K_4FeCy_6.$$

That is to say, one molecule of ferrous sulphate decomposes or renders inert six molecules of cyanide of potassium. Other things being equal, if 1 per cent. or 20lb. of ferrous cyanide existed in the ore, some 51lb. of cyanide would be rendered inert for the solution of gold, and, in fact, would be lost. This, at the average price of chemically-pure cyanide, would cost over £6 per ton.

The ferrocyanide of potassium formed according to the last reaction is reacted upon, if sufficient acid be present, by an additional quantity of ferrous sulphate, with production of Prussian blue, according to the reaction :—

$$3\ (K_4\ FeCy_6) + 6\ FeSO_4 + 3\ O = Fe_2O_3 + 6\ K_2SO_4 + Fe_7Cy_{18}.$$

This production of Prussian blue gives a blue colour to the surface of the tailings, or to the solution, and indicates at once that the washing and neutralising operations have not been carried on properly, and that a great loss of cyanide is taking place. Ferric salts, when present unmixed with ferrous salts, decompose the cyanide solution with the formation of hydrocyanic acid and precipitation of ferric hydrate, according to the reactions,—

$$Fe_2\ (SO_4)_3 + 4KCy = F_2Cy_6 + 3\ K_2SO_4.$$

With further decomposition :

$$Fe_2Cy_6 + 6\ H_2O = Fe_2(OH)_6 + 6\ HCy.$$

This means that, other things being equal, one molecule of ferric sulphate decomposes six molecules of cyanide. If 1 per cent., or 20lb., of ferric sulphate existed in the ore, very nearly the same weight of cyanide, costing £2 5s., would be destroyed.

If a mixture of ferric and ferrous sulphate, as is probable, exists in partially oxidized ores, it causes the production, when ferrous sulphate is in excess, of ferrous ferrocyanide, according to the reaction,—

$$12\ KCy + 3\ FeSO_4 + 4\ Fe_2\ (SO_4)_3 = Fe_3\ (3\ FeCy_6)_2 + 6\ K_2SO_4.$$

When ferric sulphate is in excess, the production of ferric ferrocyanide (Prussian blue), according to the reaction,—

$$18\ KCy + 3\ FeSO_4 + 4\ Fe\ (SO_4)_3 = Fe_4\ (FeCy_6)_3 + 9\ K_2SO_4.$$

These reactions show clearly that washing by water and neutralising by a caustic alkali must be employed to arrive at satisfactory and economical results. It is more than probable that many of the failures already recorded are due to the lack of these precautions. In addition to these reactions, there are many with unknown compounds, the composition of which cannot be expressed, even where the greatest precautions are used and the operations supervised with the greatest ability and knowledge.

Precipitation of the Gold.—Zinc precipitates the dissolved gold, as the cyanide has more affinity for it than for the gold.

The theoretical reaction is—

$$2\ KAuCy_2 + Zn = 2\ Au + K_2ZnCy_2$$

but more zinc goes into solution than this reaction calls for. The consumption in South Africa, as a matter of fact, is 1lb. of zinc to 1oz. of gold, instead of 1lb. of zinc to 6lb. of gold, as called for by the reaction. This excessive consumption of zinc must be ascribed to other action than the mere replacement of zinc for gold in the double cyanide of gold and potassium.

There is comparatively little exact knowledge of the reactions taking place in the zinc-precipitation boxes. One fact is known positively, and that is that hydrogen is evolved. This does not occur, however, when zinc alone is exposed to a cyanide solution, but after gold is deposited on the zinc, or when zinc is placed in contact with iron. In other words, a galvanic couple is formed, the water is decomposed, and hydrate of zinc is formed, which is attacked by the cyanide, forming a double cyanide of zinc and caustic potash. The probable reactions may be expressed as follows :—

$$Zn + 2\ HO_2 = 2\ H + Zn\ 2\ (HO). \qquad Zn\ 2\ (HO) + 4\ KCy = ZnK_2Cy_4 + 2\ KHO.$$

This production of caustic alkali explains the increased alkalinity of the solution after passing the zinc-precipitation boxes. It may be considered advantageous to a certain extent, however, as carbonic acid, which decomposes the solution, is absorbed by the caustic potash, with formation of a carbonate of the alkalies. Ammonia is formed also, as is indicated by the strong odour of that gas about the boxes. The precipitate contains, besides the precious metals, many of the base metals, which may be dissolved by the solution. The principal of these are copper, arsenic, and antimony, and, in the condition in which it is refined, large quantities of zinc and the impurities of the zinc. An incomplete analysis of the precipitate formed at the Mercier Works, Fairfield, Utah, is here given :—

Zinc	39·1
Calcium carbonate	36·7
Gold	4·4
Cyanogen	3·5
Sulphur	2·6
Iron	2·4
Undetermined residue	6·0

The gangue of the ore treated here is a silicious limestone, and the lime in the precipitate can thus be accounted for; but in what manner it has become reunited with carbonic acid is a mystery. It would seem improbable that calcium cyanide, formed in the first place by the reaction of cyanide on the calcite, was decomposed by the hydrate of zinc formed in precipitation with formation of caustic lime, which in turn was changed to carbonate by atmospheric action, for the consumption of cyanide would in this case be much higher than it is in reality (1·27lb. per ton); yet this sequence of reactions, however improbable, is the only way in which we can account for it, unless we consider the carbonate of lime to be dissolved by the alkaline solution without decomposition. In this case it might be reprecipitated by several of the reactions which occur in the zinc-boxes.

Copper was found by C. A. Aaron to be precipitated by zinc only in contact with iron, in a non-metallic form, from a solution of commercial cyanide of potassium. The precipitate dissolved with an evolution of gas, which, as it had no odour, was certainly not cyanogen gas.

According to information which I have received, there are no less than three works where the zinc has failed to precipitate the gold, and that metal, although leached from the ore, is not to be found in the solution. Careful and intelligent work will probably show where it is.

The Molloy Precipitation Process.—This process, which is said to be in successful operation in South Africa, and which certainly seems to have many favourable features, depends upon the use of sodium amalgam. The sodium in the amalgam, when in contact with a solution of gold cyanide, is replaced by gold, and itself enters the solution as sodium cyanide, which is nowise less efficacious in extracting gold than potassium cyanide. Moreover, by its use, many of the reactions causing decomposition are avoided, and a purer precipitate is formed. There is also no accumulation of formidable quantities of zinc in the solution.

The sodium amalgam is formed electrolytically from carbonate of soda, and the process of manufacture is simultaneous with the precipitation. The operations are conducted as follows: The solution passes through a trough containing mercury, in which there is a cylindrical vessel filled with carbonate of soda. The edges of this vessel are held below the surface of the mercury, so that its contents do not come in contact with the solution. The lead anode of a battery dips into the solution of carbonate of soda, the mercury itself forming the cathode. Metallic sodium is formed, which immediately amalgamates with the mercury in the bath, and the resultant sodium amalgam reacts upon the gold cyanide with production of gold amalgam and sodium cyanide, according to the reaction,—

$$Hg_nNa + KAuCy_2 = Hg_nAu + KCy + NaCy.$$

The advantages of this precipitation process, if it is proved successful, are numerous, but the patent-right is in litigation. The late U. E. Riotte made attempts to precipitate gold from cyanide solution by sodium amalgam, but his results were poor, it is said. Analagous difficulties were met with in the early days of the Russell's lixiviation process, but after much hard work these were traced to their sources—for there were several—and the remedies found. The cyanide process is essentially a chemical one, and its reaction must be carefully watched.

Decomposition of the Cyanide.—Several of the causes for the, at times, excessive decomposition of cyanide of potassium have been pointed out in the preceding sections, but there are other causes. In the first place the compound of cyanogen and potassium is extremely unstable. Not only is it decomposed by mineral acids and acid-salts, but by the action at ordinary temperatures of atmospheric carbonic acid, according to the reaction,—

$$2\,KCy + CO_2 + H_2O = K_2CO_3 + 2\,HCy.$$

Hydrocyanic acid is given off, a portion of which remains in solution and is available for the extraction of gold, but the greater part is dissipated into the air.

The cyanide is easily oxidized to cyanate :—

$$KCN + O = KCNO.$$

The cyanate is further oxidized, to carbonate according to the reaction,—

$$2\,KCNO + 3\,O = K_2CO_3 + CO_2 + N_2.$$

The nitrogen given off may cause a still further decomposition, for when a current of nitrogen is passed through a cold diluted solution of cyanide of potassium, hydrocyanic acid is evolved without the nitrogen entering into the reaction. This action, when the presence of a chemical causes a reaction between other chemicals in aqueous solutions without entering into the reaction itself, is called hydrolysis, and further reaction must be attributed to this property of caustic alkalies, which are and must be always present in a working solution of potassium cyanide. When a solution of potassium cyanide is treated with boiling alkali solution, the following reaction occurs, with formation of ammonium formate :—

$$HCN + 2\,H_2O = HCO_2(H_4N).$$

Although this reaction does not occur, since boiling alkalies are not used, analogous ones undoubtedly do, as the following reaction shows :—

$$KCN + 2\,H_2O = H_3N + KHCO_2$$

That is, ammonium and potassium formate are formed.

Returning to the case of the precipitation of lime, as at the Mercier mill, the following reaction may possibly explain the formation of calcium carbonate, if we presuppose that the lime is in the solution as cyanide of calcium:—

$$Ca\,2\,(CN) + 3\,H_2O + 2\,H = CaCO + 2\,H_3N + CO_2 + H_2O.$$

Hydrogen is always evolved when the gold is precipitated, and without it the foregoing reaction could not be completed. This reaction accounts moreover for the formation of ammonia at the zinc-boxes. The carbonic acid evolved attacks the cyanide as mentioned before, thus causing still greater decomposition of the solvent.

It will be seen, therefore, that the decomposition of the cyanide solution and loss of the solvent energy of the solution for gold may be divided under the following heads :—

1. Actual decomposition of the solution: (*a*) by acid and acid-salts present in the ore; (*b*) by atmospheric carbonic acid; (*c*) by oxidation; (*d*) by reaction owing to hydrolysis.

2. The solution of other metals than gold which are not precipitated: (*a.*) By metals or their compounds present in the ore, as oxides or carbonates of lead, which are first attacked by the caustic alkali; by oxides or carbonates of the alkali; by certain compounds of iron insoluble in water: (*b.*) by the replacement of gold in solution by zinc, in precipitation: (*c.*) by dissolving zinc hydrate formed by electrolysis in the precipitation.

It will thus be seen that these losses under incompetent management may be frequent, and in many cases may cause unprofitable results.

Operations in the Laboratory.—One of the tests to be made most frequently is the determination of the cyanide present in the solution—not only the total quantity of cyanogen present, but that available for the extraction of gold and silver. For the determination of the total cyanogen present there are several methods. The one frequently used is to add a standard solution of silver nitrate until a coloration, owing to the precipitation of insoluble silver cyanide, appears. As this method is not accurate, however, with solutions containing zinc and other metals, it will not be discussed. An easier and more accurate method is by tituration with a standard solution of iodine in potassium iodide until a blue coloration is apparent, a starch solution having been added to the cyanide solution. The reaction is as follows:—

$$KCy + I_2 = KI + ICy.$$

The solution may be checked on chemically pure cyanide, or, better yet, on sodium hyposulphite, and the cubic centimetres equivalent to 1 per cent. of potassium cyanide calculated.

For testing the percentage of available cyanide, the method devised by Mr. Bettels, of the Robinson Gold-mining Company's works in South Africa, and described by Messrs. Bolters and Clennell, is undoubtedly the best yet introduced. Two perfectly clean flasks of equal size are taken. To each of these is added a considerable bulk, say, 50 cc., of the solution to be tested, and 50 cc. of water. The liquid in both flasks will probably appear slightly turbid, but the degree of turbidity will be the same in each. Standard silver nitrate solution is run into one flask, until the slightest possible increase in turbidity is observed on comparison with the liquid in the other flask. This point is taken as indicating the conversion of the whole of the free cyanide of potassium into the soluble silver salt, and, therefore, as determining the amount of available cyanide present. If the percentage of zinc in the solution is required, the solution is evaporated by degrees, and the residue treated by any of the well-known methods of analysis for zinc. If the amount of gold is required, the residue is scorified, and the lead button cupelled. A test as to the acidity of the ore should be made, so as to calculate the amount of neutralising alkali required. For this a quantity of the washed ore may be stirred in a solution of carbonate of soda of known strength. The solution is then filtered, the pulp thoroughly washed, and the solution treated with a standard solution of sulphuric acid until carbonic-acid gas is no longer given off. The difference between the percentage of carbonate of soda originally in the solution and that remaining is the quantity on which the ore has reacted. The percentage of caustic soda, or caustic lime, may be calculated from this. The result is sufficiently accurate as a guide for practical work. The precipitate is not homogeneous, and cannot be sampled accurately, so the assayer is rarely called upon to determine the gold or silver present if it is treated at the mine. Should it be shipped, however, it will be necessary to determine the value. In this case the greatest care must be taken in sampling the silver and dried precipitate.

Ten grains of the final sample being weighed out, they are digested in nitric acid in a beaker. Sodium chloride is then added to precipitate the silver, and the residue washed upon a filter. After it is washed, the filter-paper and its contents being incinerated with care in a porcelain crucible, it is placed in a scorifier with, say, thirty grams of granulated lead, spread out with a hollow place at the centre. The ashes and metals are then covered with twenty grams of lead, a few grams of borax are sprinkled over the top, and the whole scorified. When the "eye" is about the size of a half-dime, the scorifier is removed from the muffle and the contents poured into a clean iron mould. The lead button, after the usual precautions have been taken, is cupelled. Of course this assay is made in duplicate or triplicate, and the average taken, unless there is a marked variance between them. The bullion samples, if bullion is made, should be taken by dips from the molten mass when cleaned of slag. These are granulated in *hot* water, as cold water makes irregular spatters of it, instead of those of more or less even size. These are secured, and the usual quantity weighed out for assay. In cupellation the zinc forms a gray slag, and undoubtedly there is a considerable loss of gold by volatilization with the zinc oxide. However, checks of the approximate composition of the alloy can be assayed and the loss determined.

In assaying ore or tailings it is convenient to use a large quantity of ore, preferably thirty grams (in lieu of the usual assay ton), for in the former case one milligram of cupelled gold is equal, close enough for all practical purposes, to £4 per ton. A No. 10 French crucible is large enough for this purpose.

GENESIS OF ORE DEPOSITS.

One of the most complex problems to solve at the present day is the question of how mineral ores were deposited in veins, lodes, fissures, and pipes, in which we find them. Some of the simple occurrences are easily understood, but the more complicated phenomena give rise to discordant and totally contradictory views, showing that we are yet far from the right solution of the problem. We find lodes and fissures filled with mineral ores that are never seen at the surface, bonanzas and chambers filled with rich deposits with no track to lead one on to find them, treasures locked up in the bowels of the earth encased in solid rock, and more securely hidden from the eyes of man than human ingenuity could devise. Several scientific works have been written on this subject and feasible theories propounded, but all these fall short of arriving at a true solution of the question. It is a very difficult matter to establish a satisfactory theory—so far it is only a hypothesis—to fulfil all the conditions in which mineral ores are found. Fresh explorations and exposure of deposits upset theories based on years of profound study; and what would seem to satisfactorily account for their formation in one country does not do so in another.

In carrying on mining, fresh evidences in new operations destroy the old at the same time; but every man engaged in developing these hidden treasures ought to note down the conditions in which deposits are found, so that knowledge can be gained and put together piece by piece to give us a clearer idea of the subject. The whole mining industry is in its nature transitory: but the Government of the country in which mining operations are carried on, intrusting men with the extraction of the mineral wealth, has a right to demand that the knowledge gained at the cost of its resources shall not be lost to science.

Seeing that on the two principal fields in the colony where quartz workings are being carried on there is a unanimous feeling existing among those interested in quartz workings to test the deep levels, it is therefore an opportune time to disseminate some knowledge in reference to the genesis of ore-deposits, and the views of men who have made this subject almost a life-study. It is a question which has many bearings, and, as stated at the onset, it is difficult to formulate any tangible theory that can be applied to all the conditions in which we find ore-deposits. We know that the specific gravity of the earth is 5·6; but, from what we know of the surface rocks, it is only about 2·6, therefore the interior of the earth must be a great deal denser than what is on the surface; and if we consider the interior of the earth to be or as ever having been in a molten state, the specific gravity of minerals and metals would necessarily carry them down to the lower depths towards the centre of gravity; and, if so, the metallic substances have come up in conjunction with the eruptive rocks to the surface. If this theory be taken, then we may expect to find the ore-deposit formed in two ways: (1) the deep-seated ore from ascending solutions; (2) the secondary deposits from descending solutions or lateral secretions.

It is very evident from the manner in which we find metal in the ore, especially gold and silver, it has not been deposited in the lodes in a molten condition, but is brought up from what may be termed the barysphere, from some unknown depth when it came into contact with the water (which only penetrates the earth for a short distance) but which must be in a very heated state, and containing all the elements necessary to put metals in solution. This solution would be forced up through every seam and fissure, and also through all permeable rocks; but the natural result of this would be, that there would always be a great tendency for the caps of the lodes to be richer in minerals than lower down, as the force or pressure from below would tend to force the liquid up until it met with the colder waters above, or until it was in that state when a precipitant would act quickly upon it to deposit the metals in the condition in which they are found. On the other hand, the secondary deposits, formed from a decomposition of the original rocks, or from the solubility of them, whether we have descending currents or lateral secretions, the same thing applies as to the ascending solutions. The precipitating power appears to be greater nearer the cap of the lode, or, at least, within a few hundred feet of the surface. Whatever metals are held in solution in the country-rock than they are within a reasonable distance of the surface; but whatever limit this distance may be, it certainly has not yet been determined, and it becomes a question whether the temperature of the earth has not a great deal to do with this. If we take the average increase of heat in the earth, which is 1° for every 60ft. in depth, and taking the surface temperature at 55°, we should only have to go down to a depth of 33,420ft., or six miles and a third, when a temperature will be reached which would melt lead, and, therefore, at that depth water cannot exist except in a gaseous condition. All solutions come from comparatively a shallow depth, and the inference is that the less soluble the metal, and the more difficult to precipitate, the nearer it will come to the surface before it is deposited in a metallic condition.

The question as to how our lodes are formed is of the utmost importance to the miner, and all information regarding the formation of ore-deposits should be carefully watched to see in what direction we may look for a solution of the problem: whether volcanic dykes have any influence on the richness or otherwise of our lodes, or whether the decomposition of eruptive rocks affects them in any way. If we look at the Thames, the lodes are formed in a decomposed rhyolitic substance brought together and deposited by water, or under water. And on this field there are numerous dykes of more recent volcanic origin. We know that extraordinary rich patches of auriferous ore have been, and are still being obtained from the mines in this locality, and my impression is that these volcanic dykes have an important bearing on the matter.

Professor F. Posepney, of Vienna, at the International Engineering Congress at Chicago, last year, read a valuable paper on the "Genesis of Ore-deposits"; and the remarks therein, and the theories set out, should be largely circulated amongst mining men to get them to assist in supplying any additional knowledge on the subject that may present itself in carrying on fresh explorations. The paper is too lengthy for me to quote in full, but extracts from a summary of it will be interesting to those engaged in mining pursuits. It is divided into two parts, and published as a copyright, in the "Transactions of the American Institution of Mining Engineers," New York.

PART I.—GENERAL FACTS AND THEORIES.

1. Systems of classification hitherto employed.
2. Standpoint and view of the present paper.
3. The xenogenites in general.
4. The subterranean water-circulation.
5. Origin of ore-deposits in the deep region.

PART II.—EXAMPLES OF CLASSES OF DEPOSITS.

1. Ore-deposits in spaces of discission.
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3. Metamorphous deposits.
4. Hysteromorphous deposits.

Part I.—General Facts and Theories.

1. Systems of Classification employed hitherto.

Studies of individual deposits naturally involve speculations concerning their genesis, and many such monographs contain valuable data, which, for the more thoroughly examined mining districts, are so well established, and so comprehensive, as to invite a systematic arrangement and a genetic explanation. At first, only the form of ore-deposit was considered in such classifications; afterwards the barren surrounding medium was included. From this standpoint, unfortunately still taken by some purely empirical experts, the earth's crust is primarily divided into ore-bearing and barren rocks. It was especially the true veins, at one time the principal objects of mining, which gave rise to speculations and discussions having now only a historic interest. A. Werner was the first to frame a scientific theory. He distinguished between ore-deposits contemporaneous in origin with the enclosing rocks and those of subsequent formation, and proved once for all that veins are fissures filled with ore, thus furnishing the most important characteristic for the recognition of primary and secondary formations. As to the manner in which fissures have been filled, Werner's theory, based upon a comparatively limited field of observation, has, like many of his neptunistic views, failed to maintain itself, and this question remains still without a final answer.

Curiously enough, many systematizers reproached Werner for having introduced into his system a genetic principle, which they sought to eliminate, confining themselves to the form of deposit as a guide. Thus Waldenstein distinguished (*a*) tabular deposits (beds and veins); (*b*) stock-deposits, flat-lying or steeply inclined; and (*c*) scattered masses, such as nests and pockets.

Even Cotta, otherwise an earnest advocate of geological principles, classified ore-deposits according to their form and kind as beds, veins, and masses, adding a new and somewhat indefinite group of "impregnations." J. Grimm also followed in the main the old principles of classification, including in his system the eruptive ore-breccias which he had personally examined, and the tabular segregations of ore, and pronounced not only ore-beds but also certain bed-masses to be sedimentary formations. Dr. A. von Groddeck followed genetic principles already acquiring predominance. He distinguished—(*a*) original deposits, and (*b*) deposits of *débris* (placers). The former he subdivided into (1) those formed contemporaneously with the country-rock, and stratified (ore-beds, segregated beds, &c.) or massive; (2) those formed later (cavity-fillings, veins, cave-deposits, metamorphic deposits). He pronounced ore-beds to be sedimentary, and included in his system the cave-deposits and metamorphic deposits, without describing their occurrence in detail. He declared that his system, like all others, had only the purpose of arranging the material of observation conveniently for comprehensive study, and that the manifold products of nature could not be forced into a system of classification.

Groddeck's description of the series of forms of deposits is highly original. He presents a number of types, mainly characterized by the varying material of the deposits and its manifold combinations and transitions. Evidently there was before him the ideal of combining in a systematic representation the different standpoints from which the subject was to be viewed. At least, his personal, oral communication of his views, represented one standpoint by abscessæ, and the other by ordinates, so that the intersection would determine the type of the deposit. This is true enough, but it presupposes an exhaustive knowledge from both standpoints, which we, unfortunately, do not possess. My way of looking at the subject, as it appears from his expressions in a later publication, is incomprehensible to him. It seemed to him a sort of heresy to doubt the contemporaneous deposition of the ore of the manifold copper schists with the rock. This doubt need only continue until the chemical and physical possibility of such deposition should be shown.

Groddeck's system comprises, it is true, the metamorphic deposits, but without special definition or illustrative examples. In answer to a criticism of A. Stelzner's on this point, he replies that he has included in this class those deposits also which have been formed through alteration of rock material by the process which Stelzner had proposed to call metasomasis, but that the ore-masses thus originated cannot be regarded as separate deposits, because they are only incidental phenomena of the filling of cavities—in other words, he grants but subordinate rank to one of the clearest and most important genetic aids to classification, furnished by the occurrence of rocks transformed into ore. After conceding that deposit of *débris* should probably be included among stratified deposits, he restricts his system to four chief classes: (1) stratified or sedimentary deposits, (2) massive or eruptive deposits, (3) cavity fillings, (4) metamorphic and metasomatic deposits. This brings him essentially nearer my view, which groups the first two classes together, as contemporaneous with the country-rock in origin, with the reservation, however, that the contemporaneity indicated by the stratigraphy should be verified by other evidence.

While the work of J. Grimm comprises all useful deposits, that of Groddeck is confined to ore-deposits, although it would be practicable to classify salt, coal, and other beds under his system.

In England and America the subject has been variously viewed, considerations of practice being predominant, and stratification being regarded as the specially decisive factor. This conception appears, first, in the writings of J. D. Whitney, who divides mineral deposits primarily into (1) superficial, (2) stratified, and (3) unstratified. The stratified deposits are divided into (*a*) those which the valuable mineral constitutes the mass of a bed, (*b*) those in which it is disseminated through sedimentary beds, and (*c*) those originally deposited from aqueous solution, but since metamorphosed. The unstratified deposits are again divided as irregular [subdivided into (*a*) masses of eruptive origin; (*b*) disseminated in eruptive rocks; (*c*) stock-work deposits; (*d*) contact-deposits; (*e*) fahlbands] and regular [subdivided as (*f*) segregated veins; (*g*) gash-veins; (*h*) true or fissure-veins].

We find here an explanation of the term "gash-veins," unfamiliar in Europe. Whitney says (*op. cit.* p. 225): "Segregated veins, which are peculiar to the altered crystalline, stratified, or meta-

morphic rocks, are usually parallel with the stratification and not to be depended on in depth. Gash-veins may cross the formation at any angle, but are peculiar to the unaltered sedimentary rocks. True veins are aggregations of mineral matter, accompanied by metalliferous ores, within a crevice or fissure, which had its origin in some deep-seated cause, and which may be presumed to extend for an indefinite distance downwards."

Somewhat different is the classification of R. Pumpelly, who distinguishes: I. *Surface-deposits* [(1) residuary, (2) stream-, (3) lake- and bog-deposits]. II. *Forms due to the texture of the enclosing rock or to its mineral constitution, or to both* [(1) disseminated concentrations, further subdivided as (*a*) impregnations and (*b*) fahlbands; (2) aggregated concentrations, comprising (*a*) lenticular, (*b*) irregular masses, or "stocks," (*c*) reticulated veins, or "stock-works," (*d*) contact-deposits]. III. *Forms due chiefly to pre-existing cavities or open fissures* [(1) cave-deposits; (2) gash-veins; (3) fissure-veins].

Dr. R. W. Raymond, who followed, in the main, the classification of Lottner, distinguished: I. *Superficial deposits* [(1) Deposits of *débris* (placers); (2) surface-formations in place (bog-ore, &c.)]. II. *Inclosed deposits* [(1) sheet-formed or tabular, divided into (*a*) lodes or veins, and (*b*) beds and seams; (2) mass-deposits divided into (*a*) masses and (*b*) impregnations, &c., such as pockets distributed in large deposits, isolated segregations, gash-veins, &c.].

Professor J. S. Newberry adheres mainly to the classification of J. D. Whitney, with some new matter of his own, the value of which has been justly estimated by Raymond.

An analogous line of thought is followed by J. D. Phillips. He declares that a careful study of the origin, structure, and composition of ore-deposits appears to justify their division into the following groups: (1) Superficial, formed by the mechanical action of waters; (2) stratified, (*a*) constituting the bulk of metalliferous beds formed by precipitation from aqueous solutions, (*b*) beds originally deposited from solution, but subsequently altered by metamorphism, (*c*) ores disseminated through sedimentary beds in which they have been chemically deposited; (3) unstratified, (*a*) true veins, (*b*) segregated veins, (*c*) gash-veins, (*d*) impregnations, (*e*) stock-works, (*f*) fahlbands, (*g*) contact deposits, (*h*) chambers or pockets.

In recent times the chemical standpoint has become dormant with the French school, and in a treatise of DeLaunay, which has just appeared, the attempt is, in fact, made to base a system of ore-deposits upon a purely chemical view of the subject. He distinguishes (1) ores as premature constituents of eruptive rocks, (2) containing ores deposited, no matter how, in pre-existing cavities in the rocks; and (3) where metallic substances have been laid down, either as sediments or precipitates, in marine- or fresh-water basins.

It is evident, from the foregoing mere enumeration of the names of groups and classes of the several systems, that, as a general rule, every new observation, considered important by the observer, has been added to the established traditional conception, which, however, was primarily based upon distinctions of form and kind, to which genetic principles, if recognised at all, were secondary. References can be made, in illustration, to the class of "pipe-veins," and the exhaustive paper of Dr. Raymond demolishing it. A new group was once thought to be warranted by conclusive observations—namely, *typhonic* deposits, in which the ores occur, cementing together the fragments of a brecciated mass; but it soon became apparent, by the observation of other occurrences, equally difficult to fit into the existing system, that the whole system must be transformed before it could assimilate, without destruction to itself, the new facts observed in the course of time.

But a stable and complete system could only be framed when all the controlling facts—in other words, all the ore-deposits—were accurately known. This is not likely ever to be the case. New observations are constantly made in mining, which, moreover, often obliterate the old ones, so that they cannot be verified and compared.

It is, however, absolutely necessary, in a field so complicated as that of ore-deposits, to have some general understanding, some sort of system, comprising what is known. And evidently, in framing a system, the characters of form, being the most obvious and the most familiar to the miner, would be naturally emphasized, while genetic characters were left in the background. But this ought not to check genetic investigation, or the advancing recognition of real relations. A genetic system must, indeed, involve hypotheses, and may not, for a while, be practically useful; but in time it will, like every other cultivated branch of geology, assume more permanent forms.

At the Przibram Mining Academy there was established, in 1879, a new chair of "The Geology of Mineral Deposits," which I occupied for about ten years. As the title indicates, it was not merely intended for instruction in the usual science of mineral deposits, and not as a geological course appended to the technical course in mining, as might be inferred from a title like "Mining Geology." The leading subject in view was the genesis of the useful mineral deposits.

2. Standpoint and View of the Present Paper.

The principal genetic distinction is, doubtless, between deposits contemporaneous with the country-rock and those subsequently formed in it.

The earth's crust consists of rock-elements, chiefly individualized as mineral species. Two or three dozen of them—the rock-forming minerals—constitute by far the larger part of the solid earth, as known to us. The remainder, much greater in variety and number, ornament our mineral cabinets, but form an insignificant portion of the rocks.

The greater part of this group is made up of the legion of minerals occurring in ore-deposits; and most of these have undoubtedly had a secondary origin in the rocks—for instance, all the cavity-fillings, which, of course, could only be deposited after the rocks were formed. The secondary origin of some minerals, which do not occur in cavity-fillings, is less evident. But they occur sometimes in company with those which clearly have this character, so that we may consider these numerous minerals occurring in comparatively small quantities as secondary.

We have two main groups of mineral aggregates: that of rocks, and that which we will call comprehensively the mineral deposits. The minerals of the first group belong to it, as native and

original; those of the second are foreigners to the rocks in which they occur. The two groups may therefore be designated idiogenous and xenogenous respectively, from ἰδως, one's own, and Ξενος, strange.

It is not necessary here to consider the various origin of rocks, since we take as our starting-point the rocks already formed. The clearly sedimentary rocks consist of the débris of older formations—idiogenous as well as xenogenous; and we must distinguish in them, besides mechanical sediments, chemical precipitants and organic products.

The sediment of a basin is the detritus carried into it from the land and deposited in the form of a flat wide cone. Successive conical envelopes should therefore strictly be the form of such sedimentary beds, though frequently they present apparently level parallel strata. The deposition of a precipitate, on the other hand, takes place throughout the liquid in the basin, and its form more completely represents the ideal stratum. In both sediments and precipitates we find sometimes, besides organic remains, finely-divided organic substances, forming the bituminous portions of the rocks. But the great masses of vegetable matter forming the coal-beds were, according to the most widely held opinion, deposited in swampy bottoms, and are therefore neither sediments nor precipitates. Several coal-beds, one above another, indicate a slow sinking of the basin, and its periodical filling up with detritus from the rivers to such an extent that vegetation could again take root.

A coal-basin with several beds becomes on this view the measure of the sinking, which is doubtless the cause of every large basin, but which only becomes strikingly evident when the basin contains coal-seams.

The foregoing points are mentioned because they indicate original discordances in stratification among the sedimentary layers themselves, and between these and the precipitates and organic formations.

If we find in the midst of these formations ores lying exactly between two strata, this relation is not conclusive proof of their sedimentary or precipitative origin. This must be proved in every given case; for in the present state of our knowledge we cannot understand how the metallic sulphides so characteristic of ore-deposits could be formed in that way.

As to the eruptive rocks, we do not know what they once were, as we study them only from the moment of cooling. But we observe at once that iron—a metal widely distributed in ore-deposits and in nature generally, occurs primitive in these rocks in the form of magnetite, a mineral of striking metallic appearance.

This idiogenite of the eruptive rocks can be detected without chemical aid; but with such aid we find traces of other metals besides iron; and this leads us to surmise that the eruptives have brought a whole series of heavy metals up from the "barysphere" into our "lithosphere," and that it looks as if the metals of our ore-deposits originally belonged to the barysphere. This surmise De Launay regards as already proved. He derives, as it were, *a priori*, all the heavy metals of our ore-deposits from eruptive rocks, and erects upon this hypothesis an entire system.

3. The Xenogenites in General.

With relation to the xenogenites, or mineral deposits, the first question concerns the space which any secondary mineral or mineral aggregate requires to establish its existence. It must either have found this space waiting for it, or it must have made room by driving out an original mineral.

Although we shall chiefly consider cavities formed in rocks after the formation of the rocks themselves, we must not forget that some may have been primitive in the rocks. We know that in substances of the greatest apparent density small cavities or pores must exist, since we have, for instance, by adequate pressure, forced quicksilver through them. Moreover, we encounter in the eruptive rocks larger cavities, suited to receive considerable mineral aggregates—the so-called blow-holes. These phenomena must certainly be considered, although the cavities of secondary origin will be the first subject of attention.

With regard to the filling, it is first observed that the mineral deposits upon the walls of the cavities, from liquids circulating within them, usually have a characteristic structure which we name crustification, as a companion to stratification. Most mineral crusts occur concentrically in regular succession and fill the whole cavity, except the central druse, thus forming a symmetrical crustification. This covers, however, not only the cavity walls, but the surface of every foreign body in the cavity, thus forming crusted kernels, which greatly complicate the phenomena. We shall see, however, that a geode cavity serves much better than a fissure cavity to explain the relations of crustification, and that the crusted kernels will give us no trouble in that regard.

Sometimes mineral crusts have undergone a secondary alteration—carbonates are replaced with silica, &c. The crustification is thus made less distinct, or is even obliterated. As a general rule, however, crustification is a characteristic feature of cavity-filling. The cavities are formed either by mechanical or by chemical forces, and these two classes must be sharply distinguished in view of the important *rôle* of each. The former may be the effect of exterior and foreign forces, or of such as are interior, residing in the rock itself.

Spaces of dissolution naturally occur in soluble rocks, especially limestone, and show, with wonderful clearness, the irregular course often followed by underground waters. At and near the surface we often find the cavity-formations at the contact of soluble with insoluble rocks: and we may infer that this relation affects also the subterranean circulation. Solution seldom extends to the whole mass of the soluble rock. Usually it affects a part only, in which it forms more or less irregular chains of cavities, sometimes so large that pieces of roof fall in, aud thus spaces of discission are locally produced. A cavity filled with secondary mineral, however irregular its form may be, and even though it cuts across the stratification, usually shows a predominant course, which we are thus led to recognise as the channel of circulation of the liquid to which we owe the mineral deposit.

As will be shown later, we must assume that the liquid which formed the space of dissolution also performed the filling; in fact, that both processes were almost contemporaneous. Nevertheless, they must not be confounded with the metamorphic processes where the idiogenite is expelled.

atom by atom, by the xenogenite; for the deposits in spaces of dissolution show always a distinct crustification, and hence every single crust, at least, must have found free space waiting for it.

Concerning the origin of spaces of discission, so much has been written that it cannot even be stated in abstract here. Two groups of these are distinguished. Those of the first group do not extend beyond one rock, and the force which produced them probably has its seat in that rock. In the eruptives, they are usually deemed fissures of contraction; in limes and dolomites, J. D. Whitney called them gash-veins.

The cavities of the second group extend out of one rock into another. The force which produced them resided outside of the formation. Considerable movements of one wall along the other are often evident.

As to filling the spaces of discission, it must not be supposed that they represent throughout their entire length open spaces of uniform width. The original fissure was sometimes closed, wholly or partially, by the detritus originating in the friction of the walls, or by the movement or swelling of the country-rock. Only the places remaining open would permit an active circulation of solutions, and a regular deposition from them. At points obstructed there would be no circulation, or a very sluggish one. When high pressure was present, and the rock containing interstices, the liquid doubtless penetrated from the fissure into the rock, impregnating it with mineral; or a soluble rock was attacked, and the spaces of dissolution were formed, to be filled in like manner as the fissure itself.

This explains the fact that, on the same vein-plane, rich deposits alternate with poor or barren spots, and the miner, seeking the bonanza, persistently follows the barren traces of the vein, according to the well-known fundamental law of prospecting.

From the genetic standpoint the richer portions are interesting, as sometimes occupying more or less regular belts in the vein-plane, called "channels," "shoots," "chimneys," &c. These names evidently designate the main channels through which the mineral solution passed; and the occurrence of such forms in most kinds of deposits tends to prove that, notwithstanding other differences, they were all formed in a similar way.

The *primitive* rock-cavities (pores and blow-holes) may also be filled with secondary minerals. In the former, there results a finely disseminated mineral substance, constituting such a deposit as Cotta denominated *impregnation*. Blow-holes are very often filled with minerals of the quartz family (opal, chalcedony, &c.), and we are often able to infer from the structure of such geodes the process by which they were filled.

Where the mineral solutions found no cavity already prepared, they must have conquered the necessary place by expelling a corresponding part of the original material. When one individual mineral was replaced by another, as in cases of pseudomorphs, the nature of the process can often be inferred from a comparison of the composition of the two; and the laws thus discovered may frequently be applied to the problems of the origin of mineral aggregates. Many phenomena, however, even in the formation of pseudomorphs, are hard to explain,—the fact, for instance, that in some minerals the change commences within the mass and progresses outward, &c.

Where the original material was expelled, there must have been first an access for the liquids which began and executed this effect. Such may be furnished by original minute rock-cavities, or by secondary cavities.

The original substance of the greater part of the pseudomorphs known to us was composed of soluble minerals, such as carbonates, sulphates, and chlorides, which also occur as the elements of rocks. Hence it may be inferred that metamorphous or metasomatic deposits will be especially frequent in soluble rocks like limestone, dolomite, &c., and that we may also expect such deposits to occur frequently in company with those which fill spaces of dissolution.

Pseudomorphs show us one substance in the crystal-form of another. This indication is lacking for the recognition of metasomatic deposits; yet sometimes the original rock was characterized by peculiar structure, such as laminating or jointing—as, for instance, the cellular structure of the *rauchwacke*, which is reproduced in the cellular calamine which has replaced it. Moreover, the original rock may have contained fossils, which have been replaced, with the rest, by the new mineral, retaining their form; for instance, the bivalves and molluscs of the Bleiberg limestone in Carinthia and at Wiesloch in Baden, reproduced in galena and calamine; the brachiopods of the Silurian iron-ores of central Bohemia, &c.

Most important for the study of the process are transitional forms between the earlier and the later material—for instance, coatings of the latter upon kernels of the former, such as limonite upon siderite or ankerite; and likewise important is the occurrence of regular pseudomorphs, replacing one element in a heterogeneous rock, like those of cassiterite after feldspar in the granite of Cornwall.

We must now speak more particularly concerning the method of formation of the different deposits. Probably no one doubts at the present day that they are predominantly the result of humid processes of solution and deposition. But such generalities are not enough. The processes alleged must be put upon the basis of actual causes, still operative, and capable of being proposed and discussed in explanation of geological phenomena. It is, therefore, necessary to introduce, at this point, the theoretical chapter which follows.

4. The Subterranean Water-circulation.

In treating of the genesis of mineral deposits, this department cannot well be so lightly handled as it is in most text-books of general geology. Prof. A. Daubrée, in an authoritative discussion of the subject, ascribes the mineral deposits, among other effects, directly to the liquids circulating underground. It is my desire, with the aid of personal observations incidental to my continuous study of such deposits, to present a somewhat closer view than that of Prof. Daubrée.

Surface phenomena exhibit clearly a constant circulation of liquids, and corresponding phenomena, so far as they are observable underground, indicate the persistence of this condition, so that

we must infer a subterranean circulation connected with that of the surface. We have then to consider, first, the surface phenomena, so far as they concern our purpose, and, second, the underground phenomena.

As to the former, we know that it is chiefly the solar energy which initiates the circulation by lifting above the land the water of the sea, and thereby imparting to it the potential energy which is variously exhibited in its return to the sea. The mechanical effects of flowing water in erosion, transportation, and sedimentation need not occupy us here. As to the chemical effects, we know that the mineral constituents of the rocks, dissolved through this circulation, chiefly find their way in the rivers to the sea. In regions without drainage to the ocean, the dissolved minerals are concentrated by evaporation, which may lead to precipitation. In my opinion, however, small proportions of salts are mechanically taken up in the evaporation of sea-water, as careful analyses of rain-water have proved, and this fact leads to the explanation of the salt and salt lakes in regions without drainage, &c.

(A.) The Vadose Underground Circulation.

In connection with the underground phenomena, the *ground-water* has for us a special interest. As is well known, a portion of the atmospheric precipitate sinks through open fissures, or through the pores of permeable masses, into the rocks, and fills them up to a certain level. When in a given terrain, by wells or other openings, the ground-water (that is, the water-level) has been reached at several points, it is found that these points are in a gently-inclined plane, dipping towards the deepest point of the surface of the region, or towards a point where an impermeable rock outcrops. The ground-water is not stagnant, but moves, though with relative slowness, according to the difference in height and the size of the insterstitial spaces, down the plane mentioned, and finds its way, in the first instance, directly into the nearest surface-stream, or, in the second instance, forms a spring, which takes indirectly a similar course. Thus stated, free from all complications, the phenomenon exhibits clearly the law of circulation. The atmospheric moisture evidently descends; and even the movement of the upper layer of the ground-water is only apparently lateral, but really downwards, and is determined (for equal sectional areas of the rock-interstices) by the difference in height between the water-level and the surface-outlet.

For that part of the subterranean circulation bounded by the water-level, and called the vadose or shallow underground circulation, the law of a descending movement holds good in all cases, even in those complicated ones which show ascending currents in parts. The total difference in altitude between the water-level and the surface-outlet is always the controlling factor.

When these two controlling levels are artifically changed, as often happens in mining, the law still operates. In sinking a shaft through permeable ground, it is of course necessary to lift continuously the ground-water. The water-level thus acquires an inclination towards the shaft, which may thus receive not only the flow of the immediate vicinity but even also that of neighbouring valley-systems. A shaft imparts to the previously plane water-level a depression, giving it the form of an inverted conoid with parabolic generatrix. An adit produces a prismatic depression in the water-level; and so on for other excavations. On the other hand, a bore-hole from which the water is not removed does not affect the water-level.

Atmospheric waters falling upon impermeable rocks at the surface cannot penetrate them, but must join the existing surface-circulation. The rocks are usually covered with more or less detritus, in the interstices of which the ground-water can move; and the water-level is in most cases at the boundary between the permeable surface-formation and the impermeable rock below.

These relations are complicated by the occurrence of fissures (which the ground-water of course fills), and by the communication of such fissures in depth with permeable formations, which come to the surface somewhere at a lower level, though at great distance. In such cases, as is well known, a siphon-action is set up, and the ground-water of one region may find an outlet far away, even beyond a mountain-range.

Peculiar conditions are created by the occurrence of relatively soluble rocks, such as rock-salt, gypsum, limestone, and dolomite, in which, by the penetration of meteoric waters and the circulation of the ground-water, connected cavities are formed, constituting complete channels for the vadose circulation.

It is often possible to observe directly, not only the formation but also the filling of these cavities, and thus to obtain valuable material for the explanation of the origin of xenogenites outside the vadose circulation, and not observable in the stages of formation.

It is for our purpose a most valuable fact that the phenomena of leaching indicate the path of the circulating liquids through soluble rocks, so that we can study the process in its several stages. The water flowing at the bottom of a cave in limestone is unquestionably ground-water; and it follows that the whole complex group of cavities has been eaten out by it. If in another limestone cave we see no flowing water, the current must have found some lower outlet; and the cave represents for us an ancient ground-water channel.

The many and various phenomena of the Karst region are well known: the *dolins*, *ponors*, and *katravons*—points where a surface-stream sinks into the earth; vertical openings, at the bottom of which flow subterranean streams; and caves out of which streams issue—illustrating the whole series of the entrance, the course, and the exit of subterranean waters.

Various investigations have proved that the water of the river passes through the overlying detritus to the salt-body, which it penetrates at the boundary of the impermeable rock of the hanging-wall, finding its way through separate channels to appear as saturated brine at the deepest point of the mine-workings. These channels had most frequently a cylindrical shape, smooth walls, and sometimes so great a diameter that a man could crawl in. There were always several to be seen, of which, of course, only the lowest in position brought the brine.

The explanation is simple. The water from the river, reaching the salt-body through the detritus cover, acted as the border of the salt, where the principal depressions in the surface were

located, and the saturated brine thus formed filled all interstices in the adjoining salt-body. By the leaching of such solutions into each deeper level opened in the mine, a line of maximum activity of circulation was gradually formed, which was followed also by solutions not yet saturated, with additional leaching, and the final creation of open channels as the result.

An example on a large scale of such a channel in rock-salt, created, however, without the aid of mining operations, was recently described by H. Winklehner, who found, among other striking phenomena of lixiviation in the rock-salt of the islands of the Persian Gulf, a horizontal natural channel or adit on the Island of Larak, which he was able to follow for about one mile. It expanded in places to caverns 39ft. high, without ever extending outside of the salt.

In precisely the same way were formed the channels in other less soluble rocks, such as limestone, when, the level of the entrance being above that of the exit of the ground-water, a line of maximum activity of circulation was established between the two points. This line, and the cavities developed along it, would not, indeed, always have the regular parabolic course, but would be dependent upon various influences of the stratification, the presence of rocks of unequal solubility, or even an intermixture of impermeable rocks. A mass of the latter, occurring on the line connecting the two points named, might cause the channel to bend up and down, or even in places to assume an upward inclination.

Figs. 2 and 3 illustrate these conditions. S is the soluble, I the impermeable rock; *a*, the entrance-point and *z* the outlet-point of the ground-water; *a b c z*, the line along which approximately a channel might be made, if the impermeable rock were not present. In its presence, the dissolving current must take another road, *a d z*, following more or less the contact between S and I, and in Fig. 2, descending to a depth proportioned to the relation between the original rock-interstices and the hydrostatic head, while in Fig. 3 it first surmounts the dam formed by the impermeable rock, and then plunges towards the outlet *z*. We see that in this way various channels may originate at the contact of permeable and impermeable rocks, as indeed we find them often in nature.

But when to these factors fissures are added, the conditions are essentially changed, for the circulation follows in preference the open fissures, and, if they pass through soluble rocks, enlarges them by solution.

Sometimes the position and the level of the outlet are altered—as, for instance, in the progressive erosion of valleys; and it may then easily happen that the new channel, representing the new conditions, will take a totally different direction, crossing the line of the old one.

Siphon-action is to be observed in soluble much more frequently than in permeable rocks, as the frequency of intermittent springs in limestone indicates. Such springs presuppose the existence of a siphon-like channel, through which the ground-water cannot flow to escape from the lower leg until the water-level has risen to the top of the bend of the siphon.

We have seen that the ground-water may traverse deep fissures leading to soluble or permeable rocks, and may follow such rocks for considerable distances. When the ground-water, warmed in depth, has an opportunity to reach the surface, such as is given in Fig. 6 by the difference, H, in level, a thermal spring is the result—a so-called *acrotherm*, if its water is not highly charged with minerals, and not unlike the ground-water of the place.

Artesian wells present an analogous case, also explained hitherto by the principle of hydrostatic pressure (see Fig. 7). The outcrop of the permeable layer has been assumed to be necessarily higher than the mouth of the well, in order to account for the rising of the water above the latter level. The cause has been conceived as the operation of communicating pipes, the drill-hole being one leg, and the permeable layer the other; and it has been overlooked that the latter is no open pipe, but a congeries of rock-interstices, in which the water has to overcome a great resistance, and that, perhaps, in level regions no hydrostatic head at all can be demonstrated. Certainly the powerful factor of the higher temperature, and in some cases the gaseous contents, of the ascending water were omitted from the calculation.

It would be a matter of surprise to me if the purely hydrostatic and strictly mathematical views heretofore current on this subject had not led to disappointment. In Fig. 7, the conventional diagram of an artesian well is introduced, for the purpose of stimulating further thought on the matter.

The Filling of the Open Spaces formed by the Vadose Circulation.—This is very important genetically, since it is a matter subject to current and direct observation, and capable of furnishing many conclusions applicable to inaccessible subterranean occurrences.

We can observe spaces on the bottom of which, frequently, the ground-water which excavated them is still flowing, and which are therefore filled for the most part with air. Liquids carrying various minerals drip into these spaces and leave a part of their contents on the walls; the cause of deposition being, on the one hand, the evaporation of a part of the liquid, or, on the other hand, such changes as the loss of carbonic acid precipitating as carbonate the soluble bicarbonate of lime; the oxidation of soluble ferrous to insoluble ferric oxide; the reduction of ferrous sulphate by organic matter to sulphide, &c. The form and structure of these precipitates vary at different parts of the walls. On the roof occur the *stalactites*, and on the floor (if it be not covered with water) the corresponding *stalagmites*. The wall-deposits have characteristic forms likewise; so that we can recognise by the appearance of any piece of the deposited mineral the place where it was formed. But from water covering the bottom of the cavity only horizontal deposits can originate. Sometimes the cavity is contracted, so that its whole cross-section is occupied by the liquid. If it is accessible to observation, we can then see that the deposits from the circulating liquid cover the walls uniformly.

This can be much more clearly observed in artificial conduits, where precipitation occurs. We find, for instance, in the pipes which convey concentrated brine the walls uniformly covered with a deposit, mostly of gypsum. But if air or gas is admitted into the pipes the deposit occurs only at

the bottom. We may thence infer that so long as the circulating liquid fills the whole cavity the attraction of the walls for the precipitated particles is controlling, but that when gas enters gravity becomes predominant and draws these particles to the bottom.

In opal and chalcedony geodes we can often see both forms of precipitate: the crust uniformly covering the walls, and the horizontal deposit. Fig. 4 represents a geode of iron-opal, from Dreiwasser, in Hungary, in which, besides the crustification and horizontal deposit, stalactitic and stalagmitic forms also appear. A thin crust of translucent hyalite covers all parts of the wall, including the floor. The cylindrical stalactites are also of hyalite. Some of them extend to the bottom, and are perhaps joined to stalagmites rising from the crust there. The remaining space is half filled with a milk-white, opaque, opaline substance, in which occurs a thin layer of translucent hyalite. On the same specimen several other less regular cavities are visible. All of them were lined with the hyalite crust, and some have also the opaline layers. These layers are parallel in all the cavities; and it cannot be doubted that they were horizontally deposited. The stalagmites stand at right angles to them, and were unquestionably vertical when formed. The geode certainly occupied, therefore, at the place of formation, the position shown in Fig. 4.

We must resist the temptation to describe the manifold forms of deposit in limestone caves. Fig. 5, an ideal diagram, showing a wall-accretion and stalactites and stalagmites, separate and grown together, is given, not to illustrate the variety of the phenomena, but to indicate their analogy with those of the little geode in the iron-opal of Fig. 4. It is easy to conceive that under some circumstances, particularly in old cavities lying above the water-level and not subject to further enlargement, the formation of stalactites, &c., might ultimately fill the whole space.

The floor of caves often shows deposits coloured with ferric oxide, the explanation of which is obvious. Sometimes we find in the upper caves traces of sediments also; and in one instance in an outlet cave pebbles of very hard rocks came under my observation which certainly came from the surface. The chemical reaction of the formation and filling of these caves is so simple as to need no discussion here.

Much more various observations, however, can be made in the *artificial caves* formed by mine-workings. Here we have conditions analagous to those of the natural caves, but much greater variety, since the most widely different substances come into play. The mine-workings are situated at an artificially depressed water-level, and will show, in general, processes analagous to those observed in limestone caves, particularly the formation of stalactites. From calcareous rocks, from mineral deposits, and from the mine-masonry, crusts, stalactites, and sinter are formed, analagous to those which occur in cavities at the natural water-level. Processes of oxidation will here also play the leading part, although reduction may also be effected through the more abundant organic matter in the mine-waters. Thus stalactites of pyrites, evidently reduced from ferrous sulphate by organic matter, are often found in metal-mines. A respectably large number of observations already illustrate the processes which are going on under our eyes in mines, and from which we can draw conclusions as to the destruction and creation of many minerals by circulating underground solutions. But we must not forget that these proofs apply only to the conditions of the shallow or vadose circulation, and that, for the explanation of the formation of the more ancient deposits, we must look to the rock-regions below the water-level.

To give at least one American example: Dr. R. W. Raymond found in an old Spanish mine, in the Cerillos Range of New Mexico, an iron pick-axe, the eye of which was filled with beautifully crystallized galena, evidently a reduction of lead-sulphate by the decaying wood of the handle of the pick.

It may be said, in general, that the results of the processes of oxidation, chlorination, and reduction observed in those regions of ore-deposit which lie above water-level have come to pass under conditions analogous to those just described; so that we are able to adduce extended series of proofs, not only as to formations now going on, but also as to similar formations long since finished.

(*B.*) *The Deep Underground Circulation.*

Thus far, we have considered only such processes as take place in the region above water-level, and are still, in some cases, open to our observation. As we descend to a deeper region there is less hope of encountering formative processes still active. When we penetrate by mining into the depths we artifically depress the water-level, and create conditions unlike those which attended the formation of the deposits.

But, if we compare the deposits formed below water-level, under proportionally greater pressure and at higher temperature, with those of the upper region, it appears beyond doubt that the former also must have been produced by deposition from fluid solutions.

When we compare the low solubility of certain ingredients of the deposits with the spaces in which they occur, often in large quantity, it is impossible to assume that they could have been precipitated from solutions existing in these spaces only. We must concede that immense volumes of solutions must have flowed through the spaces—in other words, that the deposits were precipitated from liquids circulating in these channels.

The formation of these cavities has been already discussed, and referred to mechanical and chemical causes. It remains to consider the manner of their filling. We have seen that the uppermost layer of the ground-water has an apparently lateral, but really descending movement; and it is very natural to imagine that this top layer slides, as it were, upon a lower mass, which is apparently stagnant. According to this conception, the deep region would be comparable to a vessel filled with various permeable and soluble materials, over which water is continually passed, so that, from the moment when all the interstices have been once filled, only the uppermost water-layer has any movement.

But, with increase of depth, the pressure of the water-column increases, as does the temperature. The warm water certainly tends to rise, if not prevented by interstitial friction, as is, no

doubt, generally the case. But where the warmed water finds a half-opened channel communicating with the upper region, it will experience much less friction on the walls, and must evidently ascend. It might thus be conceived that the ground-water descends by capillarity through the rock-interstices over large areas, in order to mount again through open channels at a few points.

This subject was viewed by A. Daubrée in a much wider significance, and extended to cover the origin of volcanic phenomena. He propounded the inquiry whether the enormous quantities of steam which are daily liberated from the deeper region are continually replaced from the surface, and, if so, how? He pointed out that this water-supply could not take place through open fissures, in which the liquid water descended at one time and the steam ascended at another, but he showed that the descent could be effected through the porosity and capillarity of the rocks. Jamin's experiments have taught us the influence of capillarity upon the conditions of the equilibrium established by means of a porous body introduced between two opposing columns. Daubrée constructed an apparatus in which the temperature in one part of the capillary passage was so high that the liquid must assume the form of steam, and thus escape the operation of the laws governing its infiltration. This apparatus comprised a sandstone slab, with water above and a chamber below, the latter provided with a manometer for measuring the pressure of the steam collected in it. The whole was exposed to a temperature of about 328° F., and steam collected in the chamber of 68cm. mercury column, indicating about 13lb. over the atmospheric pressure in the manometer, or a total pressure of about 1·9 atmosphere. The steam could only come from the water above the sandstone, through which, in spite of the pressure, a capillary filtration took place.

"The difference in pressure on the two sides of the stone not only did not drive the liquid back, but permitted it to filter quickly from the colder side (100° C.=212° F.) to the hotter (160° C.= 320° F.), and favoured the rapid evaporation and the drying of the hot stone surface."

"According to these experiments, therefore, water may be found by capillarity, operating in the same direction as gravity, against a strong interior counter-pressure, to descend from the shallower and cooler regions to deeper and hotter ones, where, by reason of acquired temperature and tension, it is capable of producing great mechanical and chemical effects."

Daubrée's experiment confirms our view that the portion of the ground-water lying below water-level is not stagnant, but descends by capillarity, and, since it cannot be simply consumed in depth, receives there through a higher temperature a tendency to return towards the surface, which tendency is most easily satisfied through open channels. Stated summarily: The ground-water descends in the deep regions also through the capillaries of the rocks; at a certain depth it probably moves laterally towards open conduits, and, reaching these, it ascends through them to the surface.

The solvent power of the water increases with temperature and pressure, and also with the duration of its underground journeying. Hence, while it is descending, it can dissolve or precipitate only the more soluble substances. But the ascending current in the open conduits is undoubtedly loaded more heavily and with less soluble substances, which, as the conditions of their solubility (temperature and pressure) gradually disappear in the ascent, must be deposited in the channels themselves.

The open channels in which the solutions ascend are not the deductions of theoretical speculation. They really exist, as we can prove by induction from appropriate observations.

The Ascending Waters encountered in Mines.—A number of such phenomena are adduced by H. Müller. For instance, in the Gottes Geschick Mine, near Schwarzenbach, in the Erzgebirge, at the depth of 110m. (360ft.), an acid spring containing CO_2 and H_2S emerges from a nickel and cobaltiferous-silver ore-vein. At the Wolkenstein Bad, an acid spring comes from the druses of an ore-vein containing a crust of barytes and amethyst. In the Alte Hoffnung Erbstollen Mine, near Mitweida, bad air and exhalations of carbonic acid led, in 1835, to an analysis of the ground-water, which proved to be weakly acid. In the Churprinz Mine at Freiberg a warm (25° C. = 77° F.) acid spring was struck on the Ludwig Spat vein at the depth of about 525ft. Besides these, Müller names a number of mineral springs occurring in Bohemia and Saxony at the outcrops of mineral veins never opened by mining. In spite of the great reserve which he exhibits, he summarises his view as follows:—

"Mineral veins and mineral springs are certainly adapted to complement each other in genetic theory. On the one hand, the ore-veins, as extended indefinitely-deep fissures, gradually filled, indicate a very profound origin for the mineral springs, and suggest variations caused by time and circumstances in the amount and mutual reactions of their contents, solid or volatile: and, on the other hand, the present relations of mineral springs explain the mode of ingress and deposit of the constituents filling the veins."

Soon after this publication, in 1864, a thermal spring of 73° F. was struck at the depth of 1,774ft. in the Einigkeit shaft, at Joachimsthal, and in the same mine at two other points similar mineral springs, rising with strong pressure, were exposed. They prevented further increase in depth of that part of the mine, and were plugged as far as practicable. The analysis made in 1882 showed that they were acid springs containing considerable silica (33 grammes per ton). In one of them arsenic was also proved to the extent of 22 grammes per ton.

The mineral waters of the Joachimsthal Mines are said to come in contact, near the place where they were encountered, with basalt-like rocks (called *wacken*), which traverse the ore-veins, and are, therefore, of later origin. In general, most of the ore-deposits of the Erzgebirge appear to have a decidedly recent origin, but even from this standpoint the mineral springs found in mining are to be regarded as nothing else than the continuation of those ascending liquids which have filled the ore-veins. Mining depresses the water-level, so that mineral waters circulating in the neighbourhood are forced to those points in the mine where there is only atmospheric pressure.

This "neighbourhood" may, indeed, extend to a comparatively long distance. For instance, the thermal spring at Carlsbad, which is the nearest to Joachimsthal, is 10·5 miles away, and

1,246ft. above sea-level, while the spring in the Einigkeit shaft at Joachimsthal was struck at 675ft. above sea-level—that is, 571ft. lower than Carlsbad. The irruption of the thermal waters of Teplitz, in Bohemia, into the lignite-mine of Dux, four miles away, which took place first in 1879, and has occurred recently since, shows plainly that subterranean communications may thus be established for long distances by mining.

Additional data for the study of these relations are furnished by the miners on the Comstock Lode, where, with the advancing depth of operations, ascending thermal waters were unexpectedly encountered, the abundance and high temperature of which presented extraordinary obstacles to mining. The great richness of the deposit was the reason that the hope of going deeper was not abandoned, as in Joachimsthal, where the only effort was to dam out the waters from existing workings; but that, on the contrary, the struggle was accepted against the waters themselves and the enormous heat which they caused in the mines.

As is well known, the upper workings on the Comstock, before any ascending waters had been encountered, were not specially hot, though warmer (70° to 75° F.) than other mine-workings in similar positions. Dr. F. Baron v. Richthofen noticed no abnormal mine-temperature, although he ascribed the Comstock to earlier solfataric action.

At a later period, upon the cutting-through of clay-partings in the rock, the hot water repeatedly broke into the workings with great force, as, for instance, in the North Ophir Mine, when, according to Clarence King, the workmen had scarcely time to escape. The water is said to have had a temperature of 104° F., and filled the workings immediately to a height of 100ft. In another case the water broke into the 2,200ft. level of the Savage Mine, and filled the large spaces both of that mine and of the Hale and Norcross up to the 1,750ft. level, or to a height of 450ft. Gas was continually but not violently evolved, and, although Professor J. A. Church reports it to have been under a pressure of 200lb. per square inch, he believes that this was not a gaseous but a hydrostatic pressure.

The water which in 1880 flooded the Gold Hill mines came from a bore-hole in the Yellow Jacket shaft, at a depth of 3,080ft., had, according to George F. Becker, a temperature of 170° F., and was heavily charged with hydrogen sulphide. In the upper levels of the mine, Becker says there is evidence of the presence of carbonic acid, and on the 2,700ft. level, where the temperature was 150° F., a deposit of sinter was found, consisting mainly of carbonates. Church remarks that it was at first believed that the repeated irruptions of water came from chains of cavities existing in the rock, but that at the time of his visit the conviction was that they came through shattered and decomposed seams, parallel with the lode, and sometimes of great thickness.

Systematic and long-continued temperature-observations in several Comstock mines enabled Becker to represent comprehensively for different lines the increase of temperature with depth; and it thus appeared that this increase was greatest in the vicinity of the lode, diminishing with the distance from the lode: that the vehicle of heat was the water; and hence that it was through the lode itself that communication with the hot depths took place, and the phenomenon denominated "solfataric action" by Richthofen was caused.

The chemical constitution of these intruding waters will be considered further on, after certain phenomena occurring nearer to the surface have received attention.

Related Phenomena near the Surface.—A sort of transition to the corresponding phenomena on the surface itself is illustrated by the mines at Sulphur Bank, California, which have furnished some of the most important data contributed by America to the study of the genesis of ore-deposits.

This is a once rich, but now, apparently, practically exhausted, quicksilver-mine, in the working of which not only thermal waters but gaseous emanations were encountered as obstacles. At the time of my visit, in 1876, an open-cut exploitation was in progress, the terraces of which had extended in some places about 16ft. below the natural surface. Sulphur, as well as quicksilver, was won; but it subsequently appeared that the sulphur-deposit was confined to the uppermost zone, while the quicksilver (or cinnabar) extended in considerable proportions to deeper regions.

At that time sulphur and cinnabar was found in a decomposed basalt, partly as the filling of irregular fissures, traversing the rock in all directions, partly as impregnations in the rock itself, which had often been reduced to a porous mass. The process of decomposition proceeded unquestionably from the fissures, which, moreover, gave forth hot mineral waters and gases. The odour alone was sufficient proof that the gases contained H_2S, to the oxidation of which into S_2HO_2 the acid reaction of the rock and its moisture was to be ascribed. The miners (mostly Chinese) chiefly followed in extraction the fissures (partly because it was the easiest way to make rapid progress, partly because the richest ores were there concentrated), and, as a result, large round blocks, often several metres in diameter, were left standing. These had a distinct shaly structure, but were so loosely held together that a kick would reduce them to ruins. In the interior of the larger, light-gray blocks was often found a nucleus of solid, dark, undecomposed rock.

The cracks were filled chiefly with an opaline mass, in which a white, opaque ingredient was variously kneaded, as it were, with a gray to black one, translucent at the edges. The specimens taken fell into irregular pieces, bounded by fissures, evidently the result of loss of volume or loss of moisture by the opaline mass.

The cinnabar formed either distinct mineral crusts in the crevices or impregnations of the porous neighbouring rock. This was true of the sulphur also; only the latter appeared, as a rule, in crystalline aggregates upon the cinnabar crusts—an indication of its later origin. Occasionally the cinnabar was deposited in beautiful crystals on the fissure-walls, but these were generally so loosely attached that it was difficult to secure a specimen.

The pyrites, mostly disseminated in the rock, tended so strongly to decomposition, evidently by reason of its saturation with sulphuric acid, that specimens containing it soon fell to pieces.

These observations suffice to show that in this case hot mineral waters ascend through fissures containing ore-crusts and opaline deposits; and when it is considered that the deposit of amorphous hydrated silica is unquestionably the work of the mineral water which decomposed the rock, and also that the cinnabar occurs in the interior of the opaline mass, the two phenomena cannot well be

separated, and it must be assumed that a metallic sulphide has here been deposited from an ascending spring. Fig. 10 represents the exposure as sketched in my note-book.

Later developments exhibit these relations still more clearly. Le Conte and Becker found a shaft 164ft. from the basalt, about 310ft. deep in sandstone, from which drifts had been run northwards at different levels under the outcrops of the deposit. It is to be regretted that their reports are not accompanied with precise descriptions of the mine-workings. In the third level (210ft. below the surface) the drift was 232ft. long, "cutting through the ore-body, and reaching only barren rock on the other side. The fourth level has been pushed 136ft., and has reached the ore-body." From these data it is hardly possible to form an idea of the position of the ore-body traversed.

The data given concerning the interior structure of the deposits are, however, important. Sandstones and slates are here broken up by fissures in such a way as often to form a breccia. Whether the fragments belong together, and whether they present the relation which may be denominated typhonic, is not stated; but it may be inferred, from the sketch of an ore-specimen from this place, that the fragments do not belong together, and that their condition has been brought about by more extreme dislocations. The subject is highly important for us; and it is attempted in Fig. 11, although the original is not before me, to represent it according to Le Conte's sketch, so as to place it side by side with the other phenomena thoroughly familiar to me.

The fragments of slate and sandstone have somewhat rounded edges, and leave varied interspaces, which are filled partly with a still soft or already indurated paste, containing finely disseminated metallic sulphides, partly with cinnabar, for the most part in coherent crusts. A part of the space is usually empty, exhibiting what may be called a central druse. Sometimes, it is said, the rock-fragments are cemented together with massive cinnabar, and kernels of rock crusted with cinnabar occur frequently.

Hot mineral water and gases carrying H_2S force their way through the interstices of the deposit, as was the case observed in the upper zones. The silica deposits are found in all stages of consolidation, from a gelatinous mass to chalcedony, and alternate with layers (crusts) of metallic sulphides (cinnabar and pyrites). Becker examined the whole neighbourhood, and extended his studies to similar ore-deposits of the region. He does not consider the basalt of Sulphur Bank, as do G. Rolland and Le Conte, to be a lava-stream, but takes it to be an eruptive rock, originating on the spot, which has overflowed a fresh-water formation of recent age. The bottom proper is a cretaceous sandstone. The ore-bearing character extends from the basalt, 52ft. thick, through the fresh-water layers in to the cretaceous sandstone. Concerning its relations in the middle layer we have no data, which is unfortunate, since the effects of the acid waters upon this calcareous material must have been considerable, and it is not unlikely that the deposit had in this region a totally different character. Fresh-water formations adjoining the deposit have preserved to a remarkable degree plant-roots, &c., transformed into lime carbonate; and it would be very instructive to study their forms as metamorphosed by the mineral water.

Concerning the chemical constitution of the warm (176° Fahr.) water, according to Becker's analysis it is extraordinarily rich in chlorides, borax, and sodium carbonate. The gas liberated from it often proved to be ammoniacal, and consisted in 1,000 parts of 893 parts CO_2, 2 parts H_2S, 79 parts CH_4 (marsh-gas), and 25 parts nitrogen.

As to the presence of other metals besides mercury, it is worthy of mention that Dr. Melville found small amounts of gold and copper in the marcasite accompanying the cinnabar, and that G. Becker found in the efflorescence from the mine-workings, besides the substances detected in the mineral water, traces of cobalt and nickel.

As will be seen, this deposit furnishes genetic data, concerning not only the ores of quicksilver, but also those of other metals. An ascending mineral spring here passes from the deep into the shallow region, and suffers, besides the reduction of pressure and temperature, the oxidation of its H_2S, from which result a strong acid and the deposition of sulphur nearest the surface.

In depth no sulphur is found, but sulphides of quicksilver and iron, upon or within deposits of silica, both being in distinct alternating mineral crusts. It cannot be doubted that cinnabar and pyrites on the one hand, and silica on the other, have been precipitated from the solution which still ascends in these channels. At most, it may be doubted whether this precipitation is still going on. Le Conte adduces in support of the probable continuance of the process the occurrence of silica sometimes gelatinous and soft, as if recently precipitated. Becker and Melville tried to obtain direct evidence of the presence of quicksilver dissolved in the ascending mineral water of to-day, but their careful investigations failed to find it. Although the water contains ingredients in which quicksilver is soluble, there is no quicksilver dissolved, and it must have been already precipitated by some agent, as, they suggest, ammonia.

There are among geologists unbelieving Thomases enough, who will believe in the presence of quicksilver in the mineral solution only when it has been actually precipitated for them; but there are those, on the other hand, who are convinced by the evidence thus far gathered that the sulphide deposits of this locality proceeded from the ascending thermal spring, whether the process of precipitation is still going on or not.

Equally weighty data are furnished by Steamboat Springs in Nevada, to which Laur and J. A. Phillips first called attention, and which Le Conte and Becker investigated thoroughly. In a valley surrounded with eruptive rocks, but underlain chiefly by Archæan rocks, thermal springs may be seen at several points emerging from north-and-south fissures. The action of these springs has covered the ground with a sinter-deposit, predominately of lime carbonates, about 49ft. thick. In this sinter may be traced many fissures, here and there still open, but mostly closed by the deposit of silica on their walls. According to a sketch given by Le Conte, these very clearly crustified deposits extend somewhat above the general level of the surface, forming single mounds or chains of mounds.

From some of them hot vapours and gases still issue, chiefly CO_2 containing H_2S. In others, such emanations have been so greatly diminished that only by listening can the liberation of vapour

in depth be perceived. Some of the fissures are completely filled, and give forth neither mineral water, steam, nor gas.

In the group, about 656ft. wide and one-sixth of a mile long, which lies nearest to the railway-track, these phenomena are most strikingly exhibited. Besides the principal substances mentioned below in the table, Becker found in this mineral water also small amounts of metallic compounds, as, for instance, HgS, a trace of Na_2S, 1 gramme per ton of Na_2SbS_3, and 8·7 grammes per ton of Na_2AsS_3.

About one mile to the west is a group of similar fissures, yielding some steam and CO_2, but no mineral water. In the mineral crusts of these, however, several metallic sulphides occur. In 1863 Laur declared that he had seen in them distinct traces of gold. In 1878, one of these fissures was opened by an adit, about 49ft. under the surface, and produced a vein-matter carrying cinnabar, which was mined for a while as quicksilver-ore. The temperature of this mine was not so high as to cause serious trouble to the workmen.

G. F. Becker carefully analysed the filling of several fissures, and found, besides hydrated ferric oxide, considerable quantities of Sb, As, Pb, Cu, Hg, sulphides, and gold and silver, as well as traces of Zn, Mn, Co, and Ni. Since from 2·2lb. to 7·7lb. of the vein-stuff were employed for each analysis, the results are specially trustworthy. The records are quoted of three analyses here, expressing them in grammes per ton (1 ton = 1,000,000 grammes):—

	I.	II.	III.
Sulphides of antimony and arsenic	...	23,000·0	150·0
Ferric oxide	...	2,500·0	...
Sulphide of mercury	1·4	2·5	1·0
Lead	88·0	21·0	...
Copper	0·3	12·0	...
Gold	0·9	1·0	...
Silver	0·3	0·3	...

(Considering the gold and silver to be alloyed in the above proportions, we should have bullion 0·750 and 0·769 fine, which is the general grade of the so-called "free gold" of Transylvania.)

The careful study of the phenomena, particularly by G. F. Becker, leaves no doubt that in this case ascending mineral waters have deposited, besides the various forms of silica (from opal to crystalline quartz), different metallic sulphides, and that the fissure-fillings exhibit a very clear instance of crustification. It is, indeed, not proved that the process is now going on. But that is not the main point. We may be content to have the proof that it has taken place.

Mineral Springs at the Surface.—When we isolate a spring characterized by high temperature, a large quantity of gas, or of matter in solution, we notice at once that its level is higher than that of the ground-water. The more thorough the isolation or walling-in, the more striking is this phenomenon, so clearly unlike that of the vadose or shallow circulation.

Isolation is usually performed by digging as deep as possible, so as to get at the spring below the loose surface-material in an impermeable rock, and then by building a well-pit to give it freer ascent. But, since the circulation of the ground-water in the loose surface is very lively, the necessary depression of the water-level in such an excavation involves the lifting of large quantities of water. Moreover, the escape of gas from the mineral spring often hinders the operation; so that there is, as a rule, little opportunity for thorongh investigations. Cases in which accurate observations have been properly recorded for preservation are very rare.

The first good fissure encountered in the bed-rock is deemed to be the channel of the mineral spring, and the well is built over it. Complete isolation from the ground-water is probably seldom practicable. Nevertheless, the mineral spring, being under higher pressure than the ground-water, will tend to exclude it from the well. The imperfection of the isolation is shown, however, when we try for any reason to pump out the well. To lower the water-level—say, 3·28ft.—we have to raise many times the amount of water which the spring itself would normally furnish (even taking into account the decreased pressure, which affects the flow in the proportion of the square root of the head). The excess, generally surprisingly great, comes from the ground-water which finds its way into the wells.

If we allow the mineral water to ascend again quietly in the well, the level rises at first rapidly, then slowly, and finally remains (in the absence of change in the height of the ground-water and in the barometric pressure) stationary at a certain height above the ground-level. This difference of height represents the ascensional force of the mineral spring.

If the spring makes a deposit at its mouth (mostly of lime carbonate, hydrated ferric oxide, and silica) it may thus build a conduit, extending above the ground-water level and the surface to the height represented by the ascensional force. Thus, we find conical mounds from the top of which mineral springs flow. This phenomenon is shown in the highest degree by geysers—*i.e.*, thermal springs in which paroxysmal developments of steam and gas occur, often forcing the water to notable heights. Some of the magnificent geysers of the Yellowstone National Park have built chimney-like conduits of considerable size. Their structure has much similarity to that of stalactites: indeed, we may recognise generally, in the various deposits of ascending mineral springs (in other words, in the products of the deep circulation), many analogies with the vadose circulation. This circumstance indicates a relation between the phenomena of the two regions which is often entirely ignored or even denied.

While, for instance, the geysers have a temperature above boiling-point, some mineral springs rise but little above the mean local temperature of the surface or of the ground-water. This may be especially observed in the acid springs; yet these are also ascending springs, and must have been formed in the deep region.

Within the vadose region we have, sometimes, ascending waters, which are, however, mostly to be explained by hydrostatic pressure. But within the deep region hydrostatic pressure can play no part; and here it is the higher temperature and the presence of gas which cause the ascension of mineral springs. The extreme instances of this kind, such as geysers, steaming springs, mud-

volcanoes, petroleum springs, &c., nobody will undertake to explain by hydrostatic pressure, and more moderate results of the same factors can scarcely, with consistency, be so explained.

It is a striking circumstance that ascending springs occur chiefly in the neighbourhood of the later eruptive rocks, such as trachyte, basalt, &c. This is emphatically the case throughout the zone which crosses Europe from west to east, in France, Germany, Bohemia, Hungary, and Transylvania. Here the warm springs and the acid springs occur thickly, while north and south of this zone they are only sporadic. Their connection in the zone with the eruptive rocks is evident, and they are often considered as the last echoes of the processes of eruption. The sporadic springs, in places where eruptive rocks play no part, must have come through deep fissures of dislocation. For example, the line of the fault along which the Alps sank below the Tertiary basin of Vienna is marked by a complete series of thermal springs.

This circumstance has another and far-reaching significance. For ore-deposits are similarly distributed. They are most numerous and most closely grouped in the neighbourhood of eruptive rocks, especially extended zones of eruptive rocks, as in the American West, and in Hungary and Transylvania, while among other rocks they are fewer and more scattered.

Chemical Constitution of Mineral Waters.—Ascending mineral springs have widely varying composition; some, like the "aerotherms," representing strictly only warmed ground-water, while others are strongly mineralised, and carry some substances almost to saturation. The material bearing on this subject is too voluminous and heterogeneous to be fully cited and discussed here. We must be content with the exhibit of a few analyses, specially interesting for the present purpose.

The following is a list of the localities, &c., represented in the table below:—

Waters Encountered in Mines.

No.	Locality.	Temperature.	Authority.
		°C. °F.	
1	Gottes Geschick Mine, Schwarzenberg	11· = 51·8	R. Richter.
2	Einigkeits shaft, Joachimsthal	28·7 = 83·6	J. Seifert.
3	The "Sprudel," in Colliery at Brüx, Bohemia		J. Gintl.
4	Comstock, Savage, 600ft. level	28· = 82·4	S. W. Johnson.
5	Comstock, Gould and Curry, 1,700ft. level	48· = 118·4	S. W. Johnson.
6	Comstock, Gould and Curry, 1,800ft. level	50· = 122·0	S. W. Johnson.
7	Comstock, Hale and Norcross	70· = 158·0	S. W. Johnson.
8	Comstock, Ophir	40· = 104·0	Attwood.

Water in Ore-bearing Fissures.

No.	Locality.	Temperature.	Authority.
		°C. °F.	
9	Sulphur Bank, Herman shaft	70· = 158·0	G. F. Becker.
10	Sulphur Bank, Parrot shaft	70· = 158·0	G. F. Becker.
11	Steamboat Springs	75· = 167·0	G. F. Becker.

Some Bohemian Thermal Springs.

No.	Locality.	Temperature.
		°F. °C.
12	Sprudel, Carlsbad	12· = 53·6
13	Kreuzbrunn, Marienbad	64· = 147·2
14	Wiesenquelle, Franzensbad	13· = 55·4
15	Urquelle, Teplitz	50· = 122·0

Weak and Strong Mineral Springs.

No.	Locality.	Authority.
16	Ottoquelle, Giesshübel	Dr. Novak Kratschmann.
17	Josephsquelle, Bilin (1875)	Dr. Ruppert.
18	Puits de l'Enclos des Celestins, Vichy	Bunsen.
19	Rippoldsau, Josephsquelle (1875)	Bunsen.
20	Rippoldsau, Wenzelquelle (1875)	Bunsen.
21	Rippoldsau, Leopoldquelle (1875)	Bunsen.
22	Kissingen, Pandurquelle (1856)	Liebig.
23	Kissingen, Rákoczyquelle (1856)	Liebig.
24	Yellowstone, Cleopatra, Mammoth Hot Springs (1888) ...	F. H. Gooch.
25	Yellowstone, Grand Geyser	T. E. Whitefield.

Analyses of some Ascending Waters.

	1	2	3	4	5	6	7	8	9	10	11	12	13
One Thousand Kilogrammes of Mineral Water contain, in Grammes:													
Alkaline carbonates	1,150	352	2,297	145	110	449	460	70	1,954	325	333	2,356	167
Earthy carbonates	510	55	729	51	...	...	...	48	54	57	17	127	146
Alkaline sulphides	82	12	37	...	...	...	...	57	...	689	172	535	500
Earthy sulphides	...	...	6	535	246	286	386	222	23	...	...	...	...
Chlorides ...	62	6	58	2	1	20	23	10	1,150	1,115	1,612	1,031	170
Silica	...	51	72	31	38	69	60	38	37	42	*391	73	8
Other substances	...	...	6	...	...	...	...	5	†1,883	†2,412	†325	...	120
Total ...	1,804	476	3,205	764	395	824	929	450	5,101	4,640	2,850	6,126	1,111

	14	15	16	17	18	19	20	21	22	23	24	25
Alkaline carbonates ...	1,167	415	1,312	3,374	5,437	...	...	...	...	...	...	378
Earthy carbonates ...	381	100	565	586	981	1,257	1,170	1,653	1,110	1,087	625	9
Alkaline sulphides ...	3,339	23	34	954	314	1,273	1,105	917	...	...	145	39
Earthy sulphides ...	...	56	...	...	...	299	240	37	978	892	559	0
Chlorides	1,213	63	30	381	534	85	69	44	6,4 41	5,998	304	619
Silica	61	48	59	43	65	57	97	86	13	4	52	303
Other substances ...	34	13	5	1	84	5	17	20	15	9	46	42
Total ...	6,195	718	2,005	5,339	7,415	2,976	2,698	2,757	8,550	7,990	1,731	1,370

One Thousand Grammes of Solid Residuum contain, in Grammes:

	1	2	3	4	5	6	7	8	9	10	11	12	13
Alkaline carbonates	632	739	717	118	278	545	495	156	383	70	117	384	150
Earthy carbonates	288	115	227	67	...	...	...	107	10	12	6	28	135
Alkaline sulphides	46	24	11	...	...	...	...	125	...	148	60	409	450
Earthy sulphides	...	...	2	699	623	347	415	492	5	...	...	...	...
Chlorides ...	34	12	17	2	2	24	25	23	225	242	569	166	153
Silica	...	107	22	40	96	83	64	83	7	9	137	12	8
Other substances	...	23	14	74	1	1	1	14	†370	†519	†111	1	104
Total ...	...	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000

	14	15	16	17	18	19	20	21	22	23	24	25
Alkaline carbonates ...	188	577	655	631	735	...	...	...	...	...	...	273
Earthy carbonates ...	61	139	283	108	132	422	436	601	130	136	362	6
Alkaline sulphides ...	539	32	17	183	42	427	412	632	...	...	84	28
Earthy sulphides ...	...	77	...	...	...	100	88	13	114	111	323	...
Chlorides	195	87	15	70	72	28	22	16	754	751	175	445
Silica	10	61	30	8	8	18	36	31	1	1	30	218
Other substances ...	7	27	...	..	11	5	6	7	1	1	26	30
Total ...	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000

* Sodium quadrisilicate, $Na_2Si_4O_9$. † Mostly sodium biborate, $Na_2B_4O_7$.

It is well known that analysts, in combining their results, do not follow the same rule. One supposes a certain acid to be united with an alkali; another gives the same acid to an earthy base, &c. What interests us in the comparison afforded by the table is the substances occurring in large proportions, the carbonates and sulphates of the alkalies and alkaline earths; the chlorides, the silica, and the quantity of organic matter (if it were determined by a uniform procedure).

It is deemed most convenient to take 1 ton of 1,000 kilogrammes (representing, for waters not too rich in mineral, the weight of 1 cubic metre), and to express the weights of the salts in grammes, to avoid decimals. In order to show the relations of the salts one to another, it is well also to represent them on the basis of 1,000 parts of the solid matter.

For the Comstock waters, the rationally-stated analysis of S. W. Johnson, from the 600ft. level of the Savage Mine, served me as a guide, according to which the figures for other mines and levels have been recalculated.

These analyses show the irruptive waters on the Comstock to be poor in dissolved substances. According to the determination of solid residuum by E. S. Bristol, this would not be the case. He finds the mine-water of the 500ft. level to contain in the Savage north drift 2,660 grammes, and in the Yellow Jacket west drift as much as 3,271 grammes, of solid material in 1 ton (1,000 kilos.). But it is a question whether these figures do not refer to ordinary mine-waters, as the term west drift seems to indicate.

The predominance of sulphates over carbonates is nothing unusual; but the decided predominance of lime, sulphate, or gypsum in the Comstock waters is unique. This relation would still remain if we should reckon a part of the sulphuric acid as combined with the alkalies. The two most trustworthy analyses of Attwood and Johnson give 222 and 535 grammes of gypsum per ton of water, and 492 and 700 grammes per ton of dry residuum. Apart from their gypsum, the Comstock irruptive waters may be classed among the weak or acrothermal springs, like those of Teplitz in Bohemia.

The Sulphur Bank and Steamboat Springs waters are distinguished from all others in the table by a considerable proportion of sodium biborate, and resemble unmistakably certain Suffioni and Lagoni waters of Middle Italy. Their degree of impregnation and their large proportion of chlorides bring them near the waters of Carlsbad and Franzensbad, Bohemia. The proportion of sodium chloride is not surprising in the American West, in the neighbourhood of undrained and therefore salt regions; but it is surprising in Bohemia, a country notoriously free from salt, in which no rock is known to contain these highly soluble substances. We must assume that they exist in the deeper region, in forms not yet decomposed, such as sodalite ($3\,Na_2Al_2Si_2O_8 + 2\,NaCl$), which must be chemically decomposed before its NaCl can be dissolved. The presence of quantities of salt smaller than those here under consideration can be attributed to atmospheric precipitation. A. Bobierre found by careful and continuous analysis of the rain-water falling in Nancy, throughout the year 1863, 14 grammes of salt per ton or cubic metre; and G. Zoppe has argued that the sometimes considerable contents of sodium chloride in the springs of the Inglesiente district, in the Island of Sardinia, can only be explained by the transportation of salt from the sea by wind. (A stormy cloud-burst, March 7, 1886, showed as much as 387 grammes per ton or cubic metre.) The salt of the atmospheric precipitation is concentrated by evaporation. In Bohemia, for instance, only one-fourth of the rainfall escapes into the Elbe; in more southern regions the whole evaporates. The descending ground-water is still further concentrated; so that in this way the salt normally found in the ascending waters may be accounted for.

But while the water of Steamboat Springs is rich in sodium chloride, the Comstock mine-water is poor, notwithstanding the comparatively near neighbourhood of the two places. Both adjoin eruptive rocks, especially basaltic outflows; but the Steamboat Springs break out of crystalline rocks. May not the ascending waters have derived their abundant sodium chloride from minerals, like sodalite, which contain it chemically bound?

Hydrogen sulphide plays an important part in the ascending waters. Its presence seems to be the cause of a greater abundance of dissolved substances. It is attributed to the decomposition of sulphates through the organic matter, traces of which are found in most of the ascending waters. By reoxidation, it produces the sulphuric acid which transforms carbonates into sulphates.

The waters flowing away from mineral springs likewise make solid deposits, which often form horizontal layers, covering considerable areas. These are the so-called travertines—formations analagous to the Carlsbad *sprudel* or *erbsenstein*, &c. But we are concerned at this point with the deposits in the spring-channel itself and in its immediate vicinity, including not merely the crusts upon the walls proper, but also those surrounding large or small fragments of rock within the channel. Many such deposits are characterized by the pisolite formation, which we may observe also in ore-deposits (concretionary iron-ores, &c.). These pisolites are evidently incrusted kernels, the crusts being proportionately much thicker than the kernels. The Carlsbad *sprudelstein* shows, indeed, the same structure on a small scale as many ore-deposits exhibit on a large scale. The pisolites, like those of Tivoli and Hamman Meskoutine, consist of lime carbonate, pure or slightly intermixed with iron oxide and silica. At the last-named locality pyrites occurs between the layers of carbonate, so that the formation must be pronounced to be crusts of lime carbonate and pyrite upon a foreign nucleus, which was elevated and incrusted so long as the ascending column of the spring had energy enough to move it.

A few words may be well added here concerning the Carlsbad *sprudelschale* and *erbsenstein*. As is well known, the *sprudel* represents an action like that of geysers, ejecting thermal water and steam to a considerable height. The precipitate at the present time is a porous, somewhat ferruginous aragonite or travertine mass. The ground from which the *sprudel* breaks forth is composed of horizontal layers of a much denser aragonite mass, which can be polished, and furnishes material for artistic lapidary-work. A part of the town of Carlsbad stands on this so-called *sprudelschale*, from whieh new thermal springs sometimes break out, and the structural history of which may have been like that of the rising succession of basins at the Mammoth Hot Springs of Gardiner River, in the Yellowstone National Park.

Certain layers of this *sprudel*-deposit are exclusively aggregates of pisolites of pea-size, whence the name *erbsenstein* (pea-stone). Evidently these have been formed, like those of the Hamman Meskoutine spring, immediately at the outflow of the mineral water. The precipitate from the solution (at the moment supersaturated) was deposited around individual rock-grains, which had found their way into the spring, to be for awhile kept in motion by its current. Successive crusts were thus deposited, until the pisolite became too large to follow the movement of the spring and sank to the bottom, where its accessible surfaces received still further precipitate-crusts. It might easily occur that single cavities might remain, into which the precipitate could not penetrate. These would represent, according to our terminalogy, the central druse. Fig. 12 illustrates this process, while Fig. 13 shows a single pisolite, including pyrite-crusts, from Hamman Meskoutine.

We can see a completely analogous result produced by falling drops at Offenbánya, where, at certain points in an adit abandoned for some thirty years, water rich in lime carbonate trickled from the roof, forming upon the floor a deposit several centimetres thick. At the spot where the drops fell directly upon the floor, a small basin-like depression was formed, in which lay, like eggs in a bird's nest, various bodies like pisolites, consisting of a sand-grain at the centre, surrounded by concentric crusts of carbonate. Some of these formations lying in the middle of the nest were quite loose, so that they were turned over by the force of the falling drops, which explained the tolerably uniform incrustation upon them. Others situated near the edge were already fixed, could not move any longer, and showed at points a deposit of sinter. (Figs. 14 and 15). Similar formations known as "bird's nest," are described by Schmidt in the old mine-workings of Riegelsdorf and Bieber. Such formations appear to be by no means rare in metal-mines. In Offenbánya, at the face of a level which had been abandoned for some years, small chips of rock were covered by the falling drops with two separate thin crusts; first, a white lustrous smithsonite, and thereupon a black, easily-detached crust of a maganiferous substance. (Fig. 16.) The pisolitic bodies formed by falling drops are not easily confounded with those formed by a flowing spring, and when such are found in the interior of an ore-filling they cannot well be ascribed to drippings.

Pisolitic forms appear in many ore-deposits. Thus the calamine deposit of Santander in Spain betrays an oölitic structure; and it has been observed in the gold-mines of Verespatak, pisolitic forms, the kernel being an aggregation of gold, and the surrounding thin crusts of carbonates of lime, manganese, and iron.

From what has been said concerning the structural relations of mineral-spring deposits, it appears that at the mouths of such springs phenomena are shown, such as crustifications of wall-deposits, pisolitic forms, &c., which we meet frequently in ore-deposits also—an additional reason for declaring the latter to have been formed by mineral springs.

5. Origin of Ore-deposits in the Deep Region.

We have seen that the mineral springs which ascend to the surface are dilute metallic solutions, and that at their outflow (the only point where we can directly observe their activity) they form deposits containing metals, among other things, and exhibiting a structure which occurs in ore-deposits likewise. We have followed to a not inconsiderable depth one ore-deposit which occurs upon an ascending spring, and have found that, apart from changes conditioned by the vicinity of the surface, it continues its character. Finally, we have encountered mineral springs in many places where mining has followed ore-deposits in depth. Joining these several links of observation, we cannot avoid the conclusion that the ore-deposits found in the deep region are the products of mineral springs, the more so since many of them have a structure and form which can only be explained as the result of precipitation from liquids circulating in channels. The deposits from these liquids contain substances which are foreign to the surface and to the shallow region, and hence could not have been brought into circulation by the descending ground-water, but must have come from a deep region, where higher temperature and pressure (the two factors increasing the solubility of all substances) exist.

Comparing the average density of the earth (which is, according to the very recent and careful investigations of R. von Sterneck, 5·6) with the average density, 2·5, of the rocks forming the earth's crust, we must admit that in the central mass substances much denser than 5·6 have been accumulated—that is to say, the deep region is the peculiar home of the heavy metals.

If we imagine ourselves standing in the deep region in front of the profile of an ore-lode, like the Adalbert at Przibram, for instance, 3,600ft. below the surface, and 1,850ft. below sea-level, we perceive a fissure-space of discission, filled with symmetric mineral crusts, chiefly argentiferous lead sulphide. Remembering that this filling has been stoped continuously to the surface, we can find no other satisfactory explanation than the hypothesis that it was brought up from still greater depths, and, in view of the comparative insolubility and the large quantity of the metallic sulphide here accumulated, it must have been deposited from perpetually-renewed, and, therefore, from *ascending*, mineral solutions. Whoever has had opportunity to study an ore-lode in the deep regions can conceive no other explanation. The miners themselves have always held this opinion; in other words, they have all been *ascensionists*. In the case of ore-deposits occupying tubular channels in soluble rocks, the origin of these spaces is not at once clear; and it has thus happened that one or another observer, misunderstanding the analogy of the substance and the conditions of filling, has suggested a different hypothesis, as, for instance, S. F. Emmons, to whose conclusions as to the Leadville deposits we shall afterward refer. It cannot be denied that there are ore-deposits permitting such a different explanation, but they occur in the shallow region only, and not in the deep region.

In the two groups of ore-deposits already discussed, and formed in pre-existing spaces, a distinct crustification leaves no doubt as to the manner of filling. Where crustification is obscure or absent, it is indeed not possible at once to offer this convincing proof of the manner of deposition. Recourse must then be had to the analogy of the substances and their paragenesis. If these correspond with the contents of spaces filled with crusted desposits, a similar origin must be inferred; that is to say, even in cases in which mineral solutions, ascending from the deep region, found no open, continuous channels, but were forced to create the necessary space by the removal of a previously-existing material, the conditions of the deep circulation still controlled. From these considerations it follows that all the deposits of the deep region are referable to one general ruling process, clearly shown to be the action of ascending mineral solutions—that is, they were all formed by ascension.

This conception is diametrically opposed to the view recently suggested by Dr. F. Sandberger, that ore-deposits are formed by so-called lateral secretion. This view was at first asserted to be universally applicable. Afterwards, the author characterized it as holding good for the majority of

ore-veins only, and restricted it by the following definition: "The theory of lateral secretion was conceived in this sense only, that the material for the filling of veins is derived from the country-rock through gradual leaching by seepage-water (*sickerwasser*), which brings the dissolved substance from both sides to the vein-fissure, where it is then converted by chemical decompositions into insoluble gangue, minerals, and ores, and so deposited."

It will be seen that he started from the wholly erroneous assumption that the ore-veins of the deep region stood open (like the fissures in a rock upon the surface), so that seepage-water from both sides could deposit material in them. That is, he conceived of a fissure containing air only, and forgot entirely that such open fissures are found exclusively above the ground-water level, below which every newly-formed fissure must be immediately filled with water. The term *sickern* corresponds with the English "seep," "trickle," or "drop," and can only be understood as describing the downward movement of a small quantity of liquid. It is thus impossible to suppose that Sandberger's meaning has been misunderstood; and we are forced to conclude that he boldly extended his conclusions to cover a region with the physical conditions of which he was unacquainted.

A lateral secretion in this sense is possible above the ground-water level only. It is indeed conceivable that even in the deep region isolated spaces may exist, from which accumulated gases find no way to the surface, and in which formations may occur similar to those in cavities above water-level; but such instances (as at Wiesloch, in Baden, and Raibl, in Carinthia) are demonstrably exceptions to the general rule above stated.

What interests us most is that, in order to establish his theory, Sandberger was forced to discredit the fact of actual deposition in the channels of mineral springs. The proof of this fact at Sulphur Bank and Steamboat Springs was highly inconvenient. Since, as he had said, "waters which flow with such rapidity as that of ascending mineral springs containing carbonic acid are shown by experience to produce no deposits in their channels, but to do this only in the immediate vicinity of their outflow," he was not convinced by the conditions shown at Steamboat Springs, where the deposits are near the outflow. With regard to Sulphur Bank, he was not acquainted with the works of Le Conte and G. F. Becker, showing that the ore-deposit is found in the channel itself. Although he did not doubt "that ore-deposits are here observed in process of formation," he recalled the well-known solubility of mercury sulphide in alkaline sulphides; argued that "the leaching of pre-existing quicksilver-deposits by alkaline sulphides presents no difficulty"; and was inclined to believe that the cinnabar-deposits near the outflow were referable to older ones. Endeavouring thus to render harmless the two instances unfavourable to the lateral-secretion theory, he summed up his consideration of them at that time with the remark that "in California no proof is presented of the formation of ore-veins by ascending springs." After reading Le Conte's account he returned to the subject in the second part of his work, asserting that in the numerous excavations connected with the walling-in of mineral springs it has never been observed that hot springs have deposited "metals" in the immediate vicinity of their channels. He confesses again that here is "unquestionably an ore-deposit, formed by the precipitation of silica and cinnabar from a hot alkaline sulphur-spring, which has found and dissolved mercury sulphide somewhere below"; and admits that hot alkaline sulphur-waters may precipitate, besides quicksilver, also gold, tin, bismuth, arsenic, and antimony—but not copper-, silver-, and lead-ores, which are often associated with the foregoing. These, he says, cannot have been deposited from hot alkaline sulphur-springs. "There is, therefore, no reason in the conditions of Sulphur Bank for restoring the ascension theory to its former authority in the science of ore-veins."

It will be seen that his chief argument is that, according to his opinion, no metallic deposit has ever been found in the channel of a spring, for he seems not to consider as conclusive the deeper workings at Sulphur Bank. Such a sweeping assertion is easy; for it is not likely that in walling a mineral spring excavations will be carried deep enough to reveal the condition of its channel proper.

Sandberger's contention comprises two propositions: (1) Metals have been found hitherto only in the ochreous deposits from mineral springs; and (2) in walling mineral springs, deposits formed in their channels have not yet been found. These two assertions are not controverted; but the conclusion, that because hitherto, in digging out mineral springs, we have found no metals in their channels, therefore they cannot be deposited in the channels but only at the outflow, is illogical.

Excavations for the walling of mineral springs do not extend to the channels of the deep region. Heavy pumping is required to penetrate even a few metres below the ground-water level; whereas, to decide this question, a depth must be reached at which the ascending spring is not altered by the descending ground-water, the oxidation and chlorination due to surface agencies no longer appear, &c.

We know that temperature and pressure, the two great factors of solubility, are continually diminished as the surface is approached; and we can directly observe one result of this change in the liberation of the carbonic acid observed at greater depths. Why should not the substances rendered insoluble by the decrease of these factors be deposited in the channels? If no such deposition has occurred, then the precipitates must have been carried upward by the current, and should be separable by filtration from the water. G. F. Becker, in filtering the Steamboat Springs water before analysis, found in the filtrate a precipitate of antimony and arsenic sulphides, with silica, which he ascribes to the fall of temperature and the action of low forms of plant-life.

But we find in various closed conduits of mineral water—*i.e.*, in artificial channels—that deposits are formed, not only at the mouth, but also in the channel itself. Why should natural channels form an exception?

It has been shown that Dr. Sandberger's chief objection to the formation of ore-deposits by ascending mineral springs is without foundation, and that the entire chain of phenomena corroborates our explanation. But the lateral-secretion theory of Sandberger suffers from several

other fundamental defects, because that theory was for a while accepted as a simple and welcome explanation of the genesis of ore-deposits, and began to hinder the progress of knowledge on that subject.

It found many disciples, especially among mineralogists, because it permitted the most extensive genetic generalisations, without requiring the observer to leave his mineral collection and laboratory, to descend into the mine, and to study the ore in the place of its origin. On the other hand, it must be confessed that the promulgation of this theory led to many investigations of rocks, which will be useful to science in other directions.

Sandberger, being convinced that he had detected foreign admixtures of the metals in silicates, felt himself warranted in explaining by his theory all ore-deposits in the silicate rocks; but he could not so well deal with those in limestone, which were cited by Stelzner as a chief argument against the universality of his conclusion. With regard to Raibl, in Carinthia, it occurred to him to examine the marly slates overlying the limestone; and finding in these, besides traces of Li, Cr, and Cu, more considerable quantities of Pb and Zn, he concluded that the metals in the ore-channels of the limestone under these slates had been leached out of the latter. This was already a descending, and not a lateral, secretion.

Dr. Sandberger submitted a statement or compilation, from which it appeared that he attached less importance to the analysis of the eruptive rocks than to that of the stratified rocks, composed of the detritus of the central Bohemian gneiss mass. According to this view, the metals of the Przibram veins came from the mica of the gneiss detritus. According to Dr. Sandberger, however, the investigation disclosed that "an essential part of the lead and silver contents of the ore-veins is due to the eruptive rocks"—which involves a modification of the above theory. This led Professor A. Stelzner in Freiberg to make a thorough test of the means employed, which showed that Sandberger's method cannot decisively determine whether the metals detected in the silicate were original constituents, or whether they are not secondary impregnations, left undissolved by the reagents employed.

It is thus rendered probable that minute metallic admixtures detected in the country-rock by Sandberger's method are really derived from the ore-deposit, *i.e.*, are not idiogenous but xenogenous. His assumptions in this field also are thus shown to be indefensible.

While fully acknowledging the great importance of chemical data for the explanation of vein phenomena, a description of a theory of ore-deposits based upon purely chemical grounds, which has just been made public by De Launay, will not be out of place. The author starts chiefly from the views of Elie de Beaumont concerning volcanic and metallic emanations, adding to these the results of the studies of Fouqué, Senarmont, Ebelmen, St. Claire Deville, Daubrée, &c. He begins with the primitive occurrence of magnetite in the eruptive rocks, which he extends to many other metals and minerals whose primitive presence in eruptives has not been demonstrated. Certain metallic substances were segregated in cooling from the molten mass; others have been dissolved from the eruptive rock in depth by "mineralisers," such as emanations of chlorine, fluorine, sulphur, &c., and have been deposited in the channels leading to the surface. De Launay is a very positive ascensionist; he also doubts the primitive deposition of ores in marine basins, and thus comes by the path of chemical speculation to results analogous to mine. Volcanic and ancient eruptive rocks; fumaroles and mofettes; geysers and thermal springs—these indicate the ways by which the metals have reached the earth's surface. But of such assumptions we must obtain assurance through observations in other directions. Views based upon purely chemical conclusions are not sufficiently convincing for us, because they are gained in the chemical laboratory under conditions different, especially as to pressure and temperature, from those which obtain in the deep region.

Manner of Filling of Open Spaces in General.

We know already that cavities, however originated, are always filled in analogous ways. We find in vein-spaces, in the spaces of dissolution, and even in individual geodes of opal and chalcedony, always the same elements of structure, though in the most widely different materials.

Considering the matter closely, we find that many things are peculiar to the shallow region, as the nearest to atmospheric influences; but some things experienced in that region may be used to explain the phenomena of deposits in the deep region also.

Since we have seen that the precipitate in an approximately horizontal pipe, entirely filled with liquid, attaches itself to the whole interior surface, the same must be true for an underground channel, and all the more if it approaches a vertical position. Under such circumstances the deposit or mineral crust will cover uniformly the whole wall-surface.

Evidently the same laws govern here as in sedimentation. When the section of the passage through which the liquid flows under a given pressure is relatively small, the deposit will take place only when the passage is enlarged. This explains the sometimes unequal distribution of ore in one and the same mineral-water channel.

As in a saturated solution a precipitate may be obtained upon any solid body introduced, so in our mineral-water channels deposits will be made upon all solid bodies—splinters or masses of rock fallen into the fissure, loose pieces of older mineral crusts, and individual crystals floating in the liquid.

The size of the rock-fragments here considered is very variable. We might include, for instance, those which are inclosed between two regular vein-branches. But we will narrow our view to what can be seen from a single standpoint in the mine, and then we observe that "horses" of several square metres' surface are uniformly crusted, like small pieces of country-rock found in the vein-filling, the only difference being, perhaps, that the crusts are thicker and more numerous upon the larger masses. The fragments of rock, either angular or already more or less rounded, form, when incrusted, the so-called sphere-, cocarde-, or ring-ores. Crusted rock-kernels may often be observed coexisting with distinct wall-crusts. Sometimes the latter are less prominent than the former, and the ore-deposit then has the appearance of a breccia or a conglomerate, the several

fragments of which are held together by the mineral crusts. If, on the plane of a given section, there appear no points of contact between the fragments, it must not be concluded that they originally hung free in the vein-space, or that they have been pressed apart at a later period by the force of crystallization of the mineral crusts, for the actual points of contact can be found in a parallel section, at least.

The frequent preparation of sections and slides of such apparently complicated structures is recommended, as by them the seeming contradictions and difficulties would be simply explained thereby. It is only a question of correct observation and representation, for which, it must be confessed, the use of colouring may be necessary. In this connection, illustrations, erroneous in this respect, have found their way even into text-books, as, for instance, the picture of cocarde-ore given by Cotta, which is taken from a careful but uncoloured drawing by Weissenbach, a part of which is reproduced in Fig. 17. Fragments of mica-slate are crusted with layers of quartz and pyrite, and in the vugs there is sometimes also manganese or brown spar. The radial appearance of the crusts in the drawing is evidently due to the position of the crystals perpendicular to the wall-surfaces, and is, as a rule, observable in all such cases. The same figure from Weissenbach has been used by A. Daubrée also, as an instance of a *filon brècheform;* but the several crusted rock-fragments are separated by heavy lines, which make the representation not only incorrect but incomprehensible.

The phenomenon may be most generally illustrated by Fig. 18, which represents a section through a gold specimen from the Kratontza ore-body at Verespatak, which is intended to be published in my monograph on the occurrence of gold in Transylvania—a series of parallel sections in colour. Four pebbles, three of quartz-porphyry and one of mica-slate, are regularly crusted with (1) a thin zone of hornstone; (2) a thin crust of pyrite, composed of several layers no thicker than paper; (3) hornstone, in which occurs (4) a zone, 0·2in. in average thickness, of fine aggregates of native gold, extending often into the next following crust (5) of quartz, containing scattered clouds of hornstone. The series ends in this specimen (6) with open central druses. But other specimens from the same deposit show also minute crusts of manganese-spar.

Fig. 11, representing the occurrence of cinnabar in the deeper workings at Sulphur Bank, is an interpretation of the description and sketch given by Le Conte. Fragments of sandstone and slate with somewhat rounded edges are regularly surrounded with crusts of cinnabar, which fill the space between, up to the central druse. Sometimes crusts of hydrated silica and pyrite appear also. Fig. 10 is a picture of a rich portion of the surface-workings of 1874. The basaltic country-rock is thoroughly cut up by irregular seams, which have disintegrated it to a shaly mass. In the seams, especially where they come together, larger spaces have been formed, often filled with decomposed country-rock, often showing separate crusts of cinnabar and opal, with a central druse. The porous material of rock and filling is impregnated with native sulphur.

Fig. 19 shows the filling of a space of dissolution, at Raibl. It is a diagram from the accurate picture in my monograph upon the deposit. A nucleus of limestone is surrounded by innumerable fine crusts of wurtzite, and more compact, but less regular, layers of galena.

Fragments of earlier mineral crusts, which have been in some way separated from their original position, are often found surrounded by mineral crusts of later origin. An example is shown in Fig. 20, representing boiler-scale from one of the Przibram pumping-plants. Here fragments of dislocated scale, about 0·08in. in diameter, are enveloped in later, thin crusts, and thus united to a breccia. The mass consists chiefly of fibrous gypsum, the fibres of which stand perpendicular to the surfaces to which they are attached.

Figs. 21 and 22 present a very distinct example, in which earlier mineral crusts, together with adhering pieces of country-rock, are surrounded by recent crusts. These figures are taken from the valuable treatise of I. Ch. Schmidt, and refer to Zellerfeld in the Harz, whence A. von Groddeck also has obtained very interesting illustrations of vein-filling.

A more complicated example from the Katrontza ore-body at Verespatak can be got where very rough ancient crusts of black hornstone and parti-coloured quartz have been cemented together by deposits of later quartz and manganese spar to a compact mass, with some central druses. Similar conditions will be seen to obtain in the so-called pipe-ores of Raibl, Figs. 25 to 28.

The variable relation between the diameter of the nucleus and the thickness of the surrounding crust naturally contributes greatly to the variety of the resulting appearances. In the pisolitic formation, for instance, the crust is many times thicker than the nucleus.

In some cases the kernels are individual crystals. I. Ch. L. Schmidt describes pisolitic forms from Warstein, in Westphalia, the kernel of which is a crystal of yellow *eisenkiesel*, about 0·2in. in diameter, showing prismatic and dihexahedric faces, and covered first with a thin, white coating, upon which are crusts of coarsely fibrous *eisenkiesel*. The edges of these are gradually rounded, until egg-shaped spheroids, about 0·5in. in diameter, are formed, touching each other at single points, and leaving interspaces, which are either filled entirely with granular *eisenkiesel*, or contain residual vugs lined with transparent, finely crystalline quartz.

Fig. 24 represents the geologically important occurrence of crusted kernels of native gold from the Màtyas Kiraly Mine at Verespatak. Minute aggregates of native gold are systematically surrounded by distinct, beautifully pink to carmine, thin crusts of rhodonite or rhodochrosite. So long as the kernels were completely separated, or were kept suspended by the disturbance traversing the cavity, these crusts were deposited entirely around each. After they had become fixed, later deposits of the same sort covered them; then followed carbonates of lime and iron; and finally came the quartz, the beautiful water-clear crystal-tips of which project into the central druses.

The occurrence of gold in manganese spar is not rare at Verespatak; ornaments cut from this material are pretty widely sold. The figure represents a piece cut for a brooch, which is in my wife's possession. It is specially interesting, also, as showing that the gold was not derived from

Fig. 1

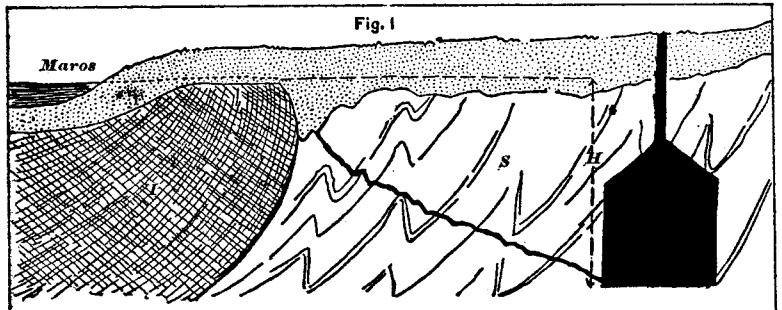


Fig. 2

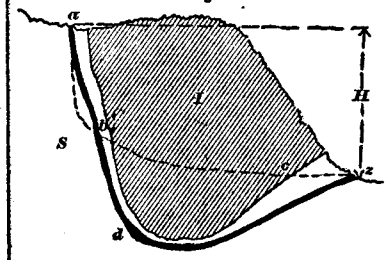


Fig. 3

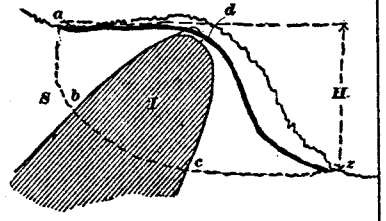


Fig. 6

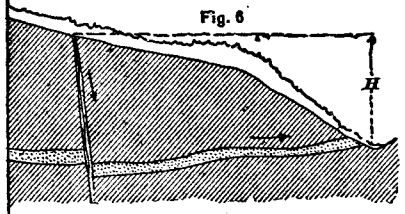


Fig. 7

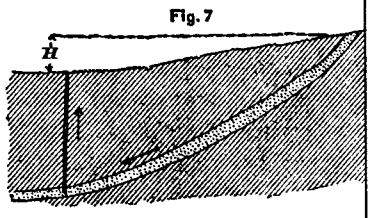


Fig. 4

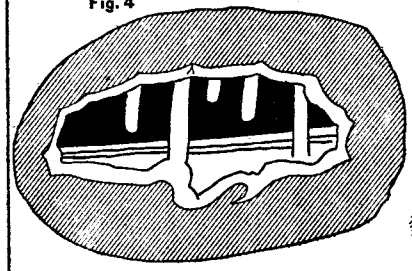


Fig. 5

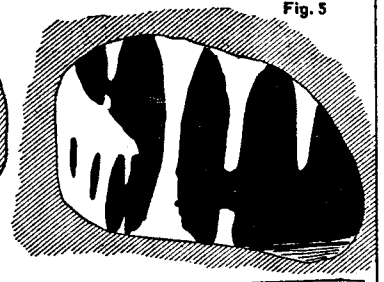


Fig. 8

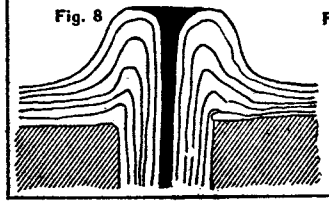


Fig. 9

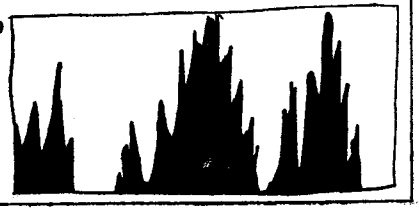


Fig. 10

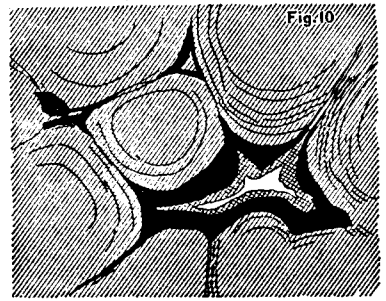


Fig. 11

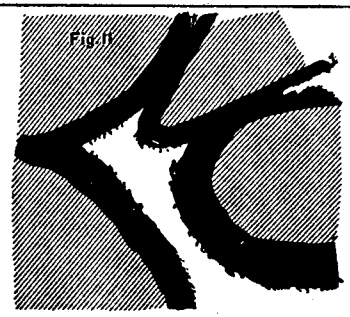


Fig. 12

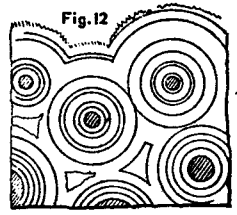


Fig. 14

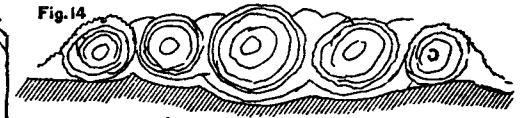


Fig. 13

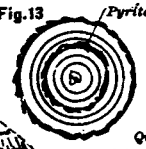


Fig. 16

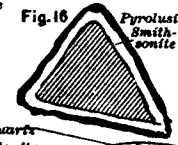


Fig. 15

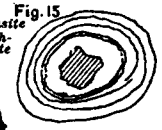


Fig. 17

Fig. 24

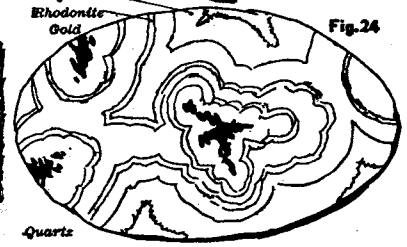


Fig. 18

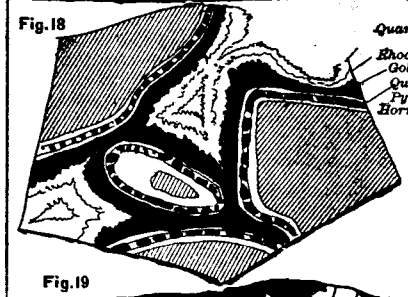


Fig. 20

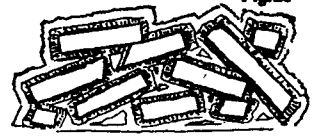


Fig. 21

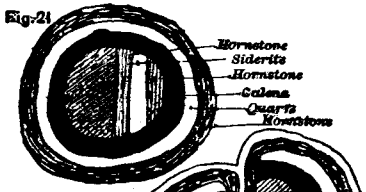
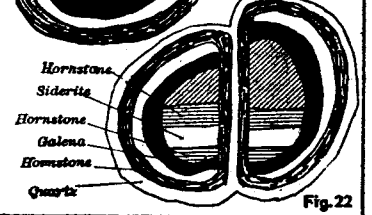


Fig. 19

Fig. 22



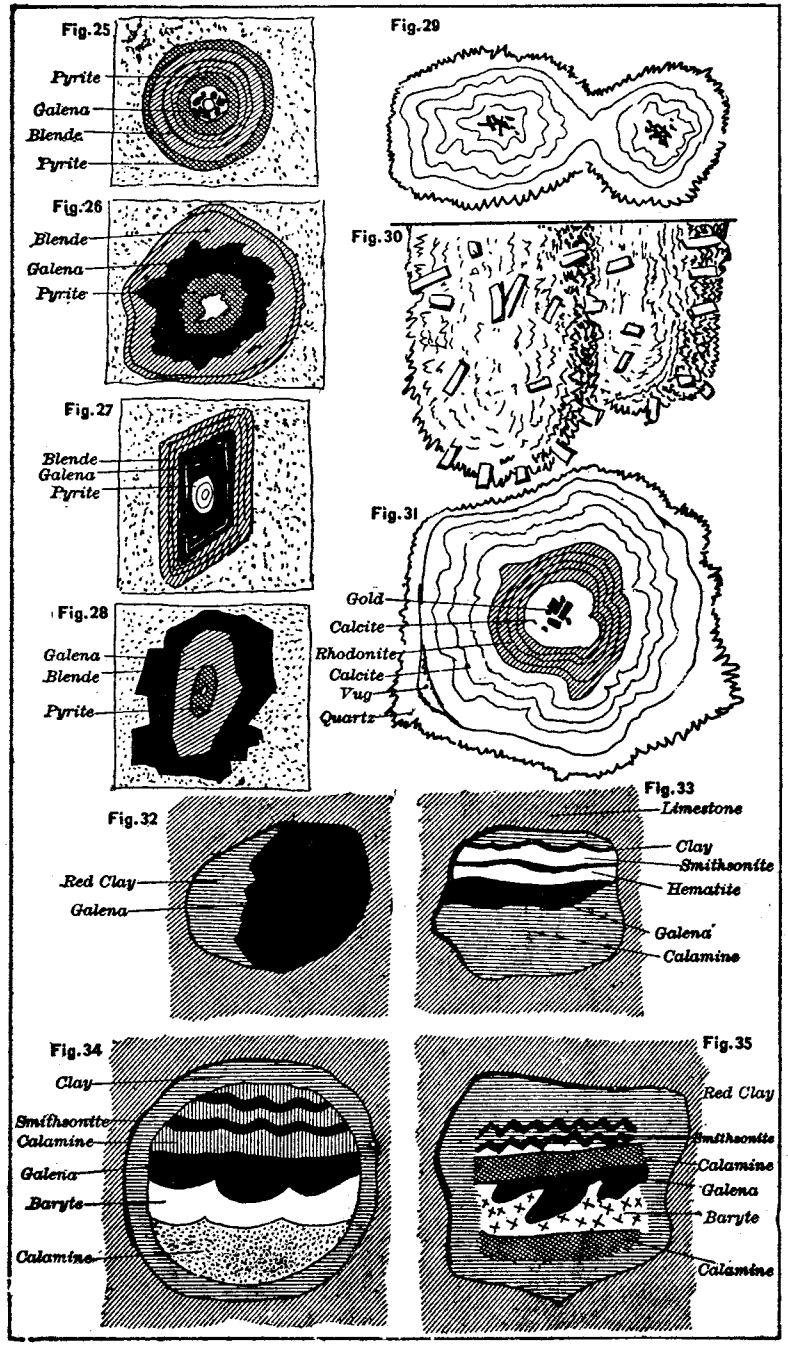


Fig. 25
Pyrite
Galena
Blende
Pyrite
Fig. 26
Blende
Galena
Pyrite
Fig. 27
Blende
Galena
Pyrite
Fig. 28
Galena
Blende
Pyrite
Fig. 29
Fig. 30
Fig. 31
Gold
Calcite
Rhodonite
Calcite
Vug
Quartz
Fig. 32
Red Clay
Galena
Fig. 33
Limestone
Clay
Smithsonite
Hematite
Galena
Calamine
Fig. 34
Clay
Smithsonite
Calamine
Galena
Baryte
Calamine
Fig. 35
Red Clay
Smithsonite
Calamine
Galena
Baryte
Calamine

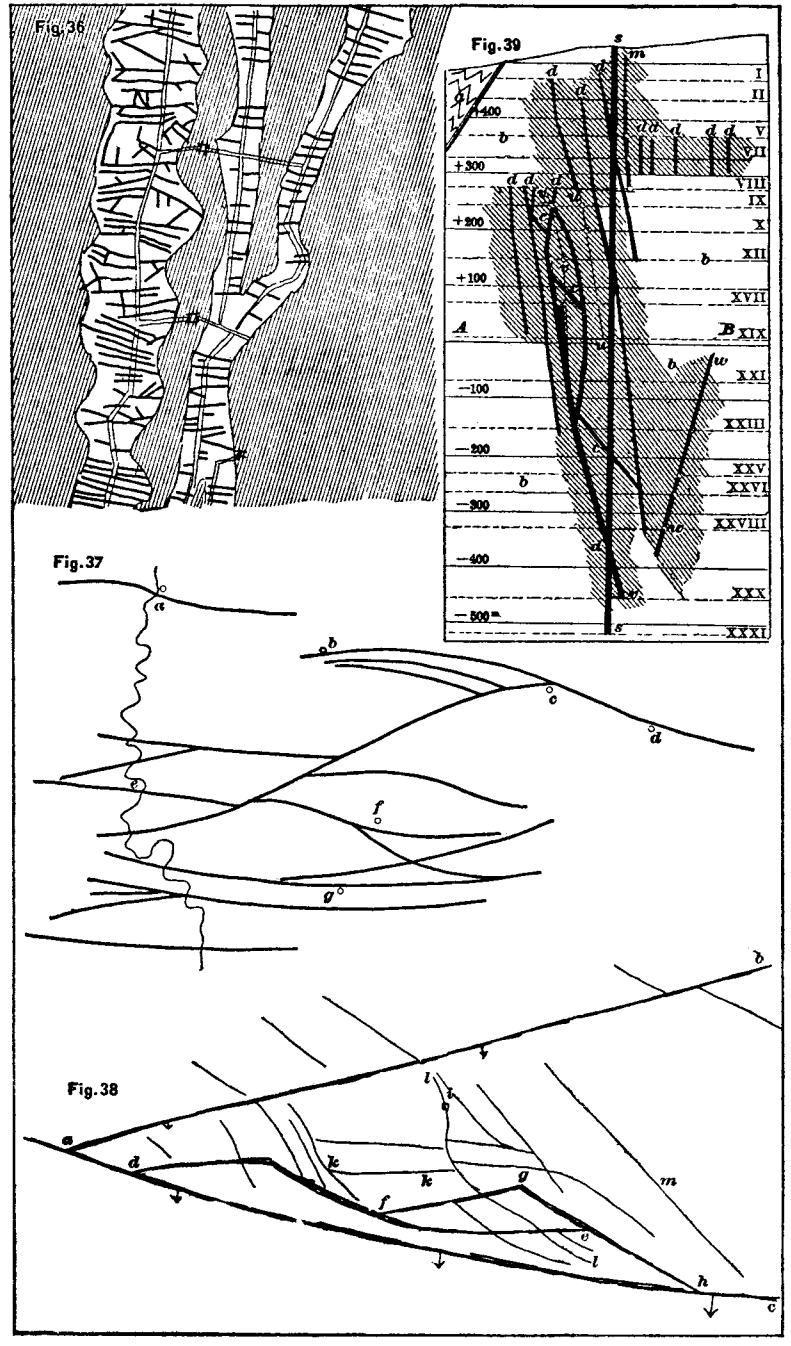


Fig. 36
Fig. 39
Fig. 37
Fig. 38

the secondary decomposition of auriferous sulphides or tellurides *in loco*, but was directly precipitated from the mineral solutions which subsequently deposited the surrounding crusts.

We have seen that within the domain of vadose or shallow circulation peculiar deposits, classed as stalactites, are very common, not only in the spaces eroded by the natural circulation of the ground-water, but also in spaces created through the artificial depression of the water-level by mining. In the latter case, since mining often follows ore-deposits into the deep region, a much larger variety of substances is exposed to alteration, so that stalactitic formations of all kinds of material may be encountered. Chiefly, however, we find in this form the results of oxidation, and it is somewhat exceptional to meet with the products of reduction, effected by organic matter in the mine. The most frequent of these are stalactites of pyrite.

This circumstance led to the opinion that stalactites in an ore-deposit should be taken as characteristic of a vadose or shallow origin, through the descending movement of the solutions which formed the stalactites. This view has been most clearly advanced by Dr. A. Schmidt. The earliest formations in the instructive Wiesloch deposits are the sulphides, marcasite, galena, and wurtzite, to the decomposition of the latter of which, through the metasomatic replacement of the carbonate of lime by the carbonate of zinc, the zinc-ore deposits are due. These he held to be clearly vadose in origin; and since the sulphides also occur in stalactites, he concluded that they likewise must have been formed by infiltration from above. The fact that these latter formations now lie below water-level, whereas the formation of stalactites requires a space filled with air or gas, only forced him to endeavour to explain this contradiction by the hypothesis of suitable elevations and depressions either of the water-level or of the land itself.

But all this would have been unnecessary if he had borne in mind that ascending liquids under a certain pressure will penetrate into a cavity from all sides, and may enter through the roof if the bottom and walls are less permeable. He distinguishes in general two forms of development in the original ore-deposition—namely, the filling of the lower part of a cavity with nearly horizontal, undulating crusts of wurtzite, with a little galena, and the stalactites which hang from the roof, there being no discoverable trace of corresponding stalagmites below. This indicates that the cavity was not wholly filled with gas, but only in its upper part, to which, consequently, the stalactitic forms are confined. As to the manner of the later decomposition of the wurtzite, which extends down to the present water-level, there can be no doubt.

Similar conditions are found in Raibl, where the stalactites, it is true, are not in their original position at the roof of the cavities, but in the midst of the filling, already broken off and surrounded by the latest mineral crust, in a dolomite spar. They seem to have occurred at many points in this deposit, but my observations were confined to two, one of which was on the fifth Johanni level, about 1,312ft. above the deepest adit (the bottom of the valley), while the other was on the seventh deep level, about 196ft. below the said adit. The former of these two points was within the influence of the ground-water.

Under the conditions, decomposition of pyrite and zinc-blende had been specially great; that of galena less so. It was often possible to extract from the dolomite mass stems of galena which were loose in it. The axis of such a stalactite-stem, frequently over 4in. long, was often an open space through which one could blow air, whence the name "pipe-ore" given to this surprising occurrence. Specimens not decomposed or in early stages of alteration showed, besides galena, crusts of pyrite and zinc-blende, concentrically disposed around the axis.

Figs. 25, 26, 27 and 28 (taken from my former treatise), and representing sections of individual stalactites, are intended to cover the variety of forms in these occurrences. Fig. 25 shows a circular stalactite in which small quantities of galena may be seen in the pyrite surrounding the axial cavity. The outer crust consists of thin layers of wurtzite. In Fig. 27 a galena mass of rhombic section, with regular striations of secretion, sits immediately on the side of the cavity. In Fig. 26 the annular mass of galena is surrounded by blende. In Fig. 28 a decomposed body of blende lies within the galena mass, which latter is deposited immediately in the granular dolomite. It will be seen that the crusts upon the stalactites present a varying order of succession, and that the stalactites have fallen from the roof at different stages of their growth.

That portion of the ore-deposit which surrounds the localities of these stalactites has an entirely normal structure, corresponding with that of other portions, and can only have been formed in the same way, namely, from ascending mineral solutions in the deep region. When, under such circumstances, a cavity contains stalactitic deposits instead of the ordinary wall-deposits, that particular part of the channel must have been filled with gas. The decomposition of the blende is due here, as in Wiesloch, to the subsequent action of the vadose circulation.

In the Mátyas Kiraly Mine in Verespatak, from which the envelopment of gold-aggregates by various metallic carbonates and quartz has already been described, there has been found also a stalactitic form of analagous composition. This specimen is in my possession, but there are two others in the National Museum at Budapest which practically came from the same mine. One of the latter is shown in Figs. 29 and 30, and my own in Fig. 31, in twice the natural size. The latter showed, after being broken from the rock in which it occurred, a projecting thread of gold; in polishing the surface several angular (and hence crystalline) gold-aggregates were found in the axis of the stalactite. The shaded portion indicates the pink manganese crusts, and the unshaded portion the colourless carbonates. The outermost crust, separated here and there from the others by a small druse, is quartz.

Wonderful occurrences of this kind must exist in the Vallé mines of Missouri; but we have only mere diagrams of them, which do not exhibit the true details and cannot be corrected with the aid of the accompanying text. The careful objective representation of a series of these tubular deposits would be a service to science. These are represented in Figs. 32 to 35.

The variety of the occurrences described above might be still further illustrated; but enough has been said to furnish from observation the elements for explaining the filling of all crustified

deposits. When the elements actually found in such deposits are taken, together with what we know of the conditions of underground circulation, no competent person can well believe in any other origin for these deposits than that of the circulation we have described. Whoever has followed the foregoing simple statement of the whole chain of phenomena will be led to distinguish sharply between the effects of the descending vadose and those of the ascending profound circulation, and to avoid the confusion of the two which sometimes characterizes the discussion of the subject.

But there remains a serious difficulty in determining the genesis of non-crustified deposits. Here the indications by which the structure and gradual growth of the deposit may be traced are at first lacking. But they will certainly be found by patient search; and this knowledge must be furnished by engineers who have opportunity to study the phenomena on the spot where they occur—namely, in the mine.

The non-crustified deposits consist, however, of the same minerals as the crustified, and cannot well have a different origin; only we are not yet in a position to offer for them similar proofs of the manner of their formation. Certainly they also are the products of ascending mineral solutions; but they were not deposited in pre-existing spaces, and consequently they show no crustification. In describing various instances of this class, I shall have occasion to adduce some data bearing upon their genetic relations.

But even the crustified deposits need to be further illustrated by examples, especially because they seldom occur in nature in pure, unmixed types. We ought not to consider ore-deposits without reference to the medium which contains them; hence we must take into consideration the country-rock, and seek to represent the analogies of nature by grouping them graphically, as it were, with relation to two axes, representing respectively the genetic class and the country-rock. We may thus distinguish the following general groups:—

Fillings of spaces of discission (fissures, &c.).

Fillings of spaces of dissolution in soluble rocks.

Metamorphic deposits in soluble rocks; in simple sediments; in crystallines and eruptives.

Hysteromorphous deposits (secondary deposits, due to surface agencies).

Part II.—Examples of Classes of Deposits.

It has been shown above that in the two regions of subterraneous circulation the formation of ore-deposits must have taken place according to different, almost diametrically opposed principles: in the vadose region through descension and lateral secretion, and in the profound region by ascension, as the product of upward currents. It has been pointed out that the deepest rocks reached by mining can scarcely be the original sources of the metallic solutions, and that these sources must lie at still greater depths.

It has been shown that the deposits of the deep region are precipitates from ascending springs. It remains to inquire, what has become of the substances which were not precipitated in such channels, but reached the surface in solution? Evidently these have been taken up, partly by the surface circulation, partly by the vadose underground currents; and, in the latter case, the deposition of such substances in the vadose region is possible. But we are not yet in a position to form a correct conception of the process of such a deposition. Possibly, many impregnations, for which we can trace no direct connection with ascending springs, yet which are certainly not idiogenous (*i.e.*, of contemporaneous origin with the rock-matrix), may have originated in this way. Possibly, the sulphides which occur confined to the neighbourhood of organic remains have been reduced from sulphates. But this must be confirmed in each case by a direct study of the facts, and not propounded as a safe generalisation for all cases.

All these conclusions are based upon the undoubtedly correct hypothesis that the individual minerals of the deposits are precipitates from aqueous solutions. The important part played by the direct products of the barysphere—the eruptive rocks—is not ignored. But there has been a tendency of late to consider the proof of any solvents as superfluous, and apparently to assume that certain minerals were segregated directly from the eruptive magma. With respect to ferriferous oxides, this view has some foundation; but the notion, apparently held in some quarters, that sulphides also were thus segregated from the magma, surpasses my comprehension. It is true that pyrite is sometimes seen upon the lavas of active volcanoes; but this occurs only when fumaroles and solfataras emit gases and vapours which decompose the rock, and therefore the agency of a solvent is not lacking.

1. Ore-deposits in Spaces of Discission.

The spaces produced in rocks by mechanical forces are predominantly fissures; but simple forms are sometimes rendered irregular by pre-existing conditions, such as those of stratification. Splitting upon a bedding-plane, coupled with a simultaneous longitudinal movement (such as gave rise to the ore-stock-works which the Norwegian miners call "lineal") may produce very complicated spaces, which must, however, be classed as spaces of discission.

Every fissure is the consequence of a tendency to dislocation transmitted into the rock. Hence the principal effect of the process is the production of the dislocation, not that of the fissure. Where yielding stratified rocks are exposed to such a force, they first bend in its direction, and the fracture takes place when the limit of elasticity is passed. In such cases it is evident that the movement precedes the fracture. Fig. 70, from Rodna, and Figure 69, from Raibl, are examples. In the latter, the gently southward-dipping contact between limestone and slate is bent and faulted by a north-and-south fissure. At Kisbánya, in Transylvania (Fig. 99), the strata of gneiss and chloritic slate striking north and south are so bent by the east and west *nagynyerges* vein as to give the appearance of an ore-bed.

Although the fissures produced by dislocating forces appear to be straight, they exhibit (as may be observed where veins have been traced for long distances) various changes of direction and more or less gradual curves. This hinders or checks the movement of one convex portion upon another,

and promotes the creation of open spaces. The dislocating force, however, continually crowds the projecting surfaces together, and thus a space already partly filled with mineral deposit may be closed, or an open space may be filled with the detritus of friction. But the space finally left open facilitates communication with the deep region, from which it is filled.

According to this conception, the vein-sheet must not be regarded (as is too often done) as a uniform plate of ore. On the contrary, it consists of several portions of very unequal value. The most valuable, doubtless, is the cavity-filling which forms the bonanza proper. In another portion the mineral solutions have been forced to penetrate the country-rock, and impregnate it with ore. A third portion remained altogether impenetrable to the solutions, and represents barren ground. These three kinds of ground may evidently show, at least in the same district, a certain regularity of relation; and, of course, it is most important to determine for a given district some law of distribution of the rich ore-bodies. In certain instances some knowledge of this distribution has been, in fact, successfully acquired for a given vein, before it had been exhausted by mining. In many other cases we cannot establish the law, even afterwards, because the most necessary records were not made during the exploitation. On the whole, we must confess that our knowledge of the laws of bonanzas is nothing to be proud of. In this respect the work of Professor Moissenet may be consulted.

Obviously, in all such investigations, the question of the origin of the fissure must be separated from that of its filling. The former can be answered only upon the broad basis of a knowledge of the stratigraphic relations of the whole vicinity, and with reference chiefly to the physical properties of the rocks, while in the latter their chemical properties come to the front.

As a rule, however, the country-rock of an ore-vein is more or less altered, not only by decomposition, but also by subsequent solidification, thus rendering much more difficult the comparison with conditions existing far from the vein. This alteration of the country-rock is universally ascribed to the mineral solutions which deposited the ore; and it is not improbable that a close study of it might enable us to draw conclusions as to the nature of these solutions. Unfortunately, petrography is still confined mainly to fresh, typical rocks, and the study of the decomposed country-rock of ore-veins has not been cultivated so much as could be wished.

All veins which exhibit friction-phenomena, such as crushed country-rock, slickensides, and striations, are structurally fault-fissures. Such a vein may be conceived, therefore, as the boundary-surface of a mass which has undergone movement. The vein-phenomena of the Hartz especially support this conception.

Some vein-fissures are confined to a given rock, and do not extend into the adjacent rock. These cannot be ascribed to structural dislocation, but must rather be considered as caused by changes of volume in the immediate formation. They are often called fissures of contraction. The most striking example which has come to my knowledge is shown in Fig. 36, which is from the gold-district of Beresov, in the Ural Mountains. Palæozoic slates are there traversed by a number of granite veins, 66ft. to 131ft. thick, and striking chiefly north and south; and each of these granite veins is again traversed by east and west gold-quartz veins, which at the borders of the granite either become barren or cease altogether. Near the Beresov is the Pysminsk district, in which the granite veins are replaced by diorite and serpentine; but, strange to say, the gold-quartz veins occupy in these rocks the same position as in the peculiar Beresov granite, locally called beresite. Judging from Beresov alone, one might suspect the veins to have been filled from the granite; but the occurrence in Pysminsk suggests caution.

Finally, the veins of the well-known very deep mines of Przibram might be ascribed to the contraction of the eruptive dykes in which they occur (although they depart here and there into the stratified rocks); but we cannot dream of deriving their metallic filling from the dykes. The Commission already mentioned, established to test the applicability of the lateral-secretion theory to Przibram conditions, found the material of the dykes to be the same in depth as in the upper zones. The largest amount of metallic contents attributed to the diorite dykes would account for a portion only of the thickness of ore in the veins. The greater part must certainly be regarded as of deep origin; and it is more convenient to treat the entire metallic contents of the veins as derived from greater depths.

Granting, then, that the vein-spaces at Beresov were formed by the contraction of the granite dykes, the vein-filling must be ascribed, like that of other deposits, to metallic solutions ascending from the deep region.

With regard to structure, the fillings of ore-veins very often exhibit distinct crustification, and sometimes even a symmetric succession of crusts from both walls to the central druse. But this phenomenon often retires into the background; crustification becomes indistinct or disappears, as is frequently the case in gold-quartz and other metamorphosed veins, in which its last traces appear in the crystal-tips of the central druse and the occasional indication of fibres perpendicular to the walls.

Sometimes one part of a vein shows distinctly a crustification which in other parts is discerned with difficulty, or is even wholly absent. Fig. 53 represents a specimen from the Drei Prinzen Spat vein in the eighth level of the Churprinz Friedrich August Mine at Freiberg. It is interesting also by reason of the two dislocations which it exhibits. The oldest vein (*a*) of quartz, with irregularly disseminated galena and zinc-blende, is traversed and faulted by a second, very clearly crustified, vein, the filling of which consists of hundreds of very thin alternate crusts of (*b*) fluorite and quartz and (*c*) barite, symmetrically arranged on both sides, with a central druse (*d*) containing a gray earthy mass. A quartz seam (*e f*) then faults both veins. The manager of the mine assured me that the specimen occurred in the vertical position in which it was sketched. (In order to be certain at all times on this important point, it is advisable, before removing a specimen from its natural position, to mark it in colour with a vertical arrow, head downward.)

Very often the crustification of a vein-formed ore-deposit is only to be traced in the appearance of the whole, since each of many irregular veinlets may represent separate mineral crusts. Accurate

pictures of such occurrences are highly instructive, since the complications are often so great that the most detailed description can convey no correct notion. Figs. 45 to 52, by reason of their small scale, do not give all the details contained in the originals from which they are taken. Figs. 45, 46, and 47 are from Weisenbach's famous book, and represent Freiberg occurrences. The rest are from Austrian publications. Figs. 48, 49, and 50 refer to Przibram, Figs. 51 and 52 to Joachimsthal. We have in Fig. 47 a specimen, so to speak, of the transition from a vein to a bedded deposit. But this is not the type called by the Germans "bed-vein" (*lagergang*), which is strictly a fissure-vein, the fissure of which coincides with the plane of stratification instead of crossing it. Sometimes it is a joint- or cleavage-plane (often confounded with the bedding) which the bed-vein occupies—a case of which has been found at Mitterberg, in Salzburg, and at the Rammelsberg, near Goslar.

In this category belong also the instances of a squeezing of strata near the vein, so that hanging- or foot-wall, or both, show for a certain distance a stratification parallel with the ore-deposit, and only beyond this zone does the normal stratification in a different plane appear. This case is best represented by Fig. 99, a sketch showing an east and west vein in a country of slate striking north and south. The occurrences at Rodna (Fig. 70) and Raibl (Fig. 69) furnish also some illustrations, though here it is chiefly barren fissures which traverse and bend the stratification.

The great number of ore-veins, as of ore-deposits in general, occur in eruptive rocks—a circumstance which doubtless indicates that their metallic contents have been derived, directly or indirectly, through these or other media, from the barysphere. The most productive ore-veins are wholly in such rocks, but others occur in stratified rocks traversed by eruptives. Comparatively few occur wholly in stratified rocks. In such cases large faults have unquestionably opened communication with the barysphere. To emphasize these relations, some illustrations will be made from well-known ore-vein districts comprising such occurrences,—

(*a.*) In stratified rocks, entirely unconnected with eruptives;
(*b.*) In the neighbourhood of eruptive masses, and partially enclosed therein;
(*c.*) Wholly within large eruptive formations.

(a.) Ore-veins in Stratified Rocks.

Genuine ore-veins entirely unconnected with eruptive rocks are not easily to be found—especially in cases of important and well-studied districts. Clausthal, in the Hartz, still comes nearest to fulfilling these conditions. The Hartz Range is a mass of folded Palæozoic strata, which lifts itself in lenticular form above the North German plateau of mainly Mesozoic rocks. The strata comprising the Hartz generally strike at right-angles to the W.N.W. direction of the axis of the range, but most of the faults are approximately parallel to this axis, so that the terms "axial" and "cross" mean here the opposite of what they would mean in ranges the main axes of which coincide with the strike of the strata.

Clausthal.—The ore-veins of Clausthal are somewhat peculiar. There are zones of altered rocks 65ft. to 262ft. wide and extending as far as about nine miles, in which the ore-bodies are somewhat irregularly distributed. These rock-zones are called vein-clay slates to distinguish them from the ordinary slates of the district; and recent careful investigations have shown that their composition practically corresponds with that of the latter. They are therefore, in fact, country-rock, altered for the most part mechanically, and only to a slight extent chemically. They are foliated; but the foliation rather parallels the planes of movement, being somewhat steep, while the strata of the surrounding region have generally but a slight dip. These zones may, therefore, be best conceived as the result of the friction of the great masses which have here been rubbed together.

In recent times, chiefly by A. von Groddeck, it had been actually proved that these zones represent great faults, along which either the foot-wall mass was moved S.W. downward, or the hanging-wall was lifted N.E. The vertical movement, measured at certain points, would be about 1,312ft.; but it is probable that the movement of one mass upon the other did not follow the true dip, and that the horizontal component was much greater than the vertical. The faulted portions of a kersantite vein discovered by Groddeck show that each southern mass was moved further west, or each northern mass further east.

The network in these zones of dislocation is also peculiar. As indicated in Fig. 37, lenticular masses have been isolated, after undergoing severally a movement in the direction of the axis of the Hartz Range; so that the whole zone of lenticular masses expresses the displacement which the solid crust has experienced. The structural significance of the zones is thus clearly disclosed as a means of communication with a deep region from which the mineral solutions ascended to deposit ores in the fissures of dislocation. An ore-vein is thus represented as the boundary of a displaced rock-mass, and so is brought into direct structural relation with the country-rock.

A glance at the geological map of the Hartz Mountains will show, however, that even this region is not free from eruptive rocks, for the stratified formations crossing the mountain axis are traversed by masses of granite, which have evidently played a part in the building-up of the range above the plateau. Moreover, according to the investigations of Dr. K. A. Lossen and others, contact-metamorphosis of the stratified rocks has proceeded from them. E. Kayser fixes the elevation of the granite between the end of the Carboniferous and the beginning of the Permian, and, since several of the faults extend into this rock, he thinks it cannot have been a factor in the fissure-formation. Lossen, on the other hand, is inclined to ascribe to the granite an active part in the formation of the ore-deposits, and to believe that these deposits were influenced by their position against the granite nucleus of the Hartz Mountains, which is said to lie steep on one side and more flat on the other beneath the sedimentary strata.

Accurate geological surveys of the Hartz have noted a large number of fault-fissures, some of which connect the two great ore-deposits of Clausthal and Andreasberg. Those which are called *ruscheln* resemble the dislocation-zones of Clausthal. They are fissures, up to 108ft. wide,

approximately parallel with the mountain axis, and filled with a clayey or fragmentary material full of striations and slickensides, and generally of dark colour.

Andreasberg.—Roughly parallel with these *ruscheln* run the silver-ore veins of Andreasberg, which carry the ore only on one side of the *ruscheln*, and lose their ore when they approach the latter. It was formerly imagined that the two main *ruscheln* enclosed a lenticular mass of the country, to which the silver-ores were confined; and H. Credner still expresses this view. But Kayser observes that the mines have disclosed a convergence of the *ruscheln* to the west only, and that a similar convergence to the east has been purely assumed from analogy, whereas the surface indications are rather those of a wider separation in that direction. (See Fig. 38.)

We have here a case in which the ores occupy, not, as in Clausthal, a previously-prepared zone of dislocation, but a network of veins. H. Credner has pointed out that the mineral solutions were unable to penetrate the walls of the dislocation-zones, and conceived in this connection that these walls enclosed a lenticular body of rock. But the main question concerns the origin of the more recent network of fissures. We must assume that, when the dislocation-zones were formed, the mineral solutions had no opportunity to enter them, because (as was the case in many great faults—*e.g.*, those of Przibram) no spaces of discission were formed. Afterwards, however, a second system of fissures originated, adjusting itself to the conditions created by the first, and producing rock-fragments, the relatively slight movement of which did not fill the interstitial spaces with the detritus of friction.

But, outside of the angle between the *ruscheln*, there are also veins which, considering their direction, may be continuations of the silver-veins inside, although, being differently filled, they are not so regarded.

It was formerly attempted to connect two eruptive rocks with the formation of these ore-veins: the granite which appears to the north, beyond the fault-fissures, and the diabase which touches them at many points to the south. The latter, however, is now considered to be a stratified layer in the series of the country. Both rocks have been passive in the formation and the filling of the fissures, and we must look again to the deep region as the source of the ores.

(b.) Ore-veins in the Neighbourhood of Eruptive Masses.

The Erzgebirge.—It would be impossible here to pass in review the innumerable veins of the *Erzgebirge*, in Saxony and Bohemia. Such a review will soon be furnished by the publication of a work on this subject by the eminent Saxon mining geologist, H. Müller (who has received the honorary title of "Gangmüller," to distinguish him from the many other Müllers of Germany). In this region veins in the greatest variety occur in gneiss, with here and there an eruptive dyke; but the latter can scarcely be considered as more than indications of a former communication with the barysphere.

Besides different porphyries and diorites, there is an occasional dyke of basalt. At Joachimsthal, in Bohemia, we can recognise Pre- and Post-Basaltic ore-deposition. We find here, as in many other districts, two vein-systems at right-angles; one striking N. to S., and accompanied with porphyry dykes; the other striking E. to W., and accompanied with dykes of basalt and (according to recent views) phonolite. The E. to W. fissures are occupied partly by basaltic dykes, partly by ore-veins which were deposited some before and some after the basalt, a satisfactory proof that the fissures were formed at the period of basaltic eruption. How far the basalt took part in the ore-deposition, however, has not yet been shown.

In the basaltic and "basalt-wacke" dykes of this district, at the considerable depth of some 984ft. below the surface, petrified tree-trunks were found, a fact which furnishes an analogy to the reported discoveries in the Bassick Mine, in Colorado.

Przibram.—An entirely different picture is presented by Przibram, in Central Bohemia, where we encounter not only a great structural fault, but also eruptive dykes, which are followed by most of the ore-veins.

In central Bohemia the general strike is N.E. to S.W. for all rocks except the diorite dykes, which strike N. to S., thus varying 45° from the prevailing direction. Above the granite lies, first, a formation of Pre-Cambrian slates; upon this follows unconformably the Cambrian system, consisting below of conglomerates and sandstones, and above of fossiliferous slates. Sections across the strike show repetitions of the Pre-Cambrian and Cambrian strata due to great faults, which likewise strike N.E. to S.W. (Fig. 40).

The one main fault, which has been exposed by mining to the depth of 3,600ft., is properly a so-called *wechsel*, by which the older stratum (in the hanging-wall of the fault) has been slid over the later stratum (in the foot-wall). Several other faults, similar in character, though not explored on an equal scale, occur in the district; and it may be imagined that, before this shoving together of the Palæozoic strata of central Bohemia, they must have occupied a much larger area than at present.

This main fault, called the "*lettenkluft*," is constituted by a zone of clay and crushed rock, from 6·5ft. to 33ft. wide. At Przibram itself the sandstones which contain the ore are succeeded in the hanging-wall side by Pre-Cambrian slates. A little further south-west, at Bohutin, granite appears on the hanging-wall of the *lettenkluft*—evidently, as the cross-section indicates, the granite foundation, here outcropping a second time, of the whole Palæozoic series.

Numerous N. to S. dykes occur, and in the ore-bearing zone they are so close together that some cross-sections show them to constitute almost one-third of the total rock-mass. The ore-veins are mostly in these diorite dykes. Only occasionally do they enter the stratified rocks, returning soon to the dykes they have left, or to others of the group. In dip also they mainly follow the dykes, so that we may here assert with confidence that the already-existing dykes determined the formation of the ore-bearing vein-fissures.

As already narrated in Part I., this district was made a test of Sandberger's lateral-secretion theory. Careful and repeated analysis showed the presence of metals in the rocks, but could not

decide the question whether these metals were primitive ingredients or secondary impregnations. Since such metallic traces occur in both the eruptive and the sedimentary rocks, but cannot possibly be in both cases primitive, it is probable that they are in both cases secondary. There is then in this case, notwithstanding the connection of the ore-veins with the dykes, no proof that they were formed by the leaching of the country-rock. If the vein material (as is very likely) was derived from eruptive rocks, these were situated much deeper than the eruptive rock disclosed down to 3,600ft. below the surface, or 1,640ft. below sea-level.

The Cambrian sandstone basin of Pzribram is unsymmetrical; one side dips gently north-west, the other (next to the fault) slightly south-east. In the latter part, which is also more highly metamorphosed, lies the bonanza or rich ore-ground, which therefore starts from the intersection of the great structural fault with the zone of eruptive rocks—in other words, from the point relatively nearest to the barysphere.

In the steeply-dipping sandstone series certain strata are petrographically characteristic; and, when these are traced to the intersecting dykes, it becomes clear that the latter (and hence the ore-veins also) are fissure-faults. Thus Fig. 39, a section through the Franz Joseph shaft, shows dislocations of the strata (adinole beds) as great as about 656ft.

It should be added that the dykes present different kinds of eruptive rock, and that they are generally decomposed in the neighbourhood of the ore-veins— a result naturally to be attributed to the action of the mineral springs; also, that stratified rocks show, near the granites, a contact-metamorphosis which has converted them into hornstone. This phenomenon recalls the Hartz, especially the St. Andreasberg district.

(c.) *Ore-veins wholly within Large Eruptive Formations.*

Hungary.—If we turn to Hungary, we find many veins wholly included in eruptive rocks. One of the best known districts is that of Schemnitz, which presents in geological conditions the nearest analogue of the Washoe district and the Comstock Lode in Nevada.

In both cases various eruptives, principally Tertiary, such as diorite, andesite, trachyte, and rhyolite, ranging to basalt, are spread over a Mesozoic (mainly Triassic) foundation. The north and south extension of these masses and of the ore-veins they contain is alike in both districts. The number of veins at Schemnitz is very large, and they exhibit a very great variety of filling. In some of them so-called "ore-columns"—*i.e.*, specially rich ore-channels (chimneys or shoots)—have been recognised. Those in the Grüner vein, according to M. V. Lipold, are short horizontally, but much prolonged in the direction of their pitch obliquely on the dip of the vein. In other ore-veins—*e.g.*, in the Spitaler master-lode, which is about 131ft. wide, and has been traced for five miles; also in the Bieber and other veins—the ore-bodies are said to have covered large areas of the vein-sheet. The ore richest in gold is reported to be the so-called *zinnopel*, a crust consisting of jasper, with pyrite, chalcopyrite, and galena, which surrounds fragments of an earlier quartz crust.

In the trachyte range of Vihorlat Gutin, which runs north-west and south-east, approximately parallel with the Hungarian boundary, there is a series of gold- and silver-mining districts containing occasional large veins with numerous small ones. Among the former are those of Nagybánya and Felsöbánya, where several domes of trachyte or of andesite, breaking through the late Tertiary "*Congerien*" strata, are in turn traversed by large veins, which split up near their outcrops, so as to exhibit in vertical cross-section a fan-shaped arrangement.

Further east is the Kapnik mining district, containing a series of separate veins; then comes Rota, similar in character; and finally (over the line in Transylvania) the district of Oláhlápos-bánya, the veins of which are partly in the eruptive rock, partly in the old Tertiary strata which it traverses.

Throughout the range silver-ores predominate, occasionally with a considerable gold-value. In the eastern portion copper-ores appear.

The Dacian Goldfield.—In south-western Transylvania, in the Dacian gold district, all the gold-mines are grouped in connection with four separate eruptive zones of recent origin. The main rock of the region is Cretaceous sandstone, with occasional exposures of Jurassic and Triassic strata, the latter of which include heavy outflows of melaphyre, and also masses of crystalline rocks. The recent eruptives, comprising porphyry, diorite, andesite, basalt, &c., occur in a triangle, the base of which is formed by the widest range, the Cietrasian, which strikes north-west and south-east, and in which are the mines of Nagyag, Mugura, Füzesd, Boiza, and Ruda. In a second approximately parallel range are the mines of Faczebaja and Almás; in a third, those of Vulkoj and Verespatak; and in a fourth, forming the apex of the triangle, those of Offenbánya.

These mines, which are for the most part very ancient (Pre-Roman), will be treated fully in a monograph now in course of preparation. In the whole Dacian gold district the predominant deposits are fissure-veins, sometimes represented by mere "knife-blade" seams, continuous for short distances only. In some places, as in the celebrated Verespatak district, other types of deposit are represented, the ores of which, however, also occur in spaces of discission—namely, in eruptive breccias—between the related fragments, in the form which elsewhere have been called typhonic masses; but these are ore-bearing only where they are in contact with the ore-veins. The same is true of the conglomerates into which these breccias sometimes pass, and in which the ore takes the place of the interstitial cement. For further elucidation we show in Fig. 41 a breccia, and in Fig 42 a conglomerate. In both these specimens the rock is quartz porphyry with quartz crystals of pea-size. In Fig. 41 the interior of the fragments is considerably decomposed, whereas the exterior shows a thin layer either of undecomposed rock or of material subsequently impregnated with silica from the open interstices, and thus made capable of resistance. Sometimes the porphyry is found to be traversed by a complex network of fissures, filled, except as to some wider spaces of intersection, with a clastic mass like sandstone. The interstices of the conglomerate, Fig. 42 (except the spaces containing crusts of manganese spar and quartz), are filled with a clastic cement, mostly silicified into hornstone.

This sort of ore-filling is comparable in some degree with ore-deposits in soluble rocks when the filling has passed from the space of discission proper into the rock, after room has been made for it in the latter by dissolution. In the cases before us such room was made by the partial washing away of the (probably clayey) cement of the breccias and conglomerates.

Verespatak.—The gold-district of Verespatak is situated at the north end of the second eruptive range. The two porphyry masses of Kirnik and Boi form a centre, around which sandstone and porphyry-tufa lie almost horizontally, and in part uncomformably, upon folded Cretaceous sandstones below. The whole district is surrounded by a zone of trachytes, andesites, and their lavas, which once (as may be inferred from the fragments remaining on the porphyry and tufa) overspread the entire district, and have been removed by erosion, laying bare the two older eruptive masses of the porphyry.

A funnel-shaped depression seems to have been formed in the folded Cretaceous strata, from the middle of which ascended the porphyry-outflows, furnishing also the material for the porphyry-tufa which fills this funnel-shaped basin.

The principal gold-bearing rock is the porphyry, yet the tufas and the Cretaceous rocks near the porphyry-outflow carry gold, whereas no gold or ore of any kind occurs in the trachytic and andesitic lavas which once covered the region.

Vulkoj.—At Vulkoj, however, at the southern end of the second eruptive range, almost the opposite is the case. Here the older and deeper quartzose rock carries little ore, while gold abounds in the overlying andesites. Several mines of the Dacian gold district have encountered in depth the stratified rocks through which the eruptives came, and the result has generally been disastrous to the miner, the ore-veins having either ceased entirely or become pinched to barren fissures. In the first case it would appear that the vein-fissures had been formed by the contraction of the eruptive material. But, in general, it should be said that these phenomena are by no means clearly and reliably reported. The prejudices of the miners play too large a part in their reports. This much is certain, that any fissure, in passing from one rock to another, is likely to exhibit a certain irregularity in both direction and filling, and that a change of this kind should not be allowed to discourage at once all further exploration.

In some cases there has been found, below an eruptive rock containing ore-veins, a decomposed breccia of the same, which was quite barren. The great porphyry mass of Kirnik, at Verespatak, has been pierced through and through with ancient and modern workings like the pores in a sponge. In recent years deep adits have been driven into it to reach fresh ground, but with unsatisfactory results. A short time ago the deepest of these adits encountered in the nucleus of the Kirnik mass not the ore-bearing porphyry but decomposed clastic rock and porphyry-breccia, which may be supposed to be the filling of the crater-opening. The Vulkoj mass, which has been almost cut into two halves by very ancient open-workings along its crest, contained a series of N. to S. veins, the richest of which (the Jeruga) was cut in depth by adits from both sides. On the south side appears a slaty Cretaceous rock, underlying the porphyry, and extending (see Fig. 43) upon the Jeruga plane, with two offsets, to the deepest adit on the north side, where it strikes the decomposed breccias, in which the very rich ores mined above can no longer be found to continue.

As to the continuation of the veins in the slaty rock, the following facts are pertinent. West of the Vulkoj mass, in the sandstones and slates, there is another goldfield, that of Botesiu, the veins of which are analogous, both in strike and in ore-filling, to those of Vulkoj. Botesiu shows no eruptive rocks; nevertheless, a study of the whole region shows that the formation of its vein-fissures must have been connected with them, and it is even not impossible that they may once have extended as far as this, and may have been removed by subsequent erosion. It follows that we must assume the Vulkoj veins to extend below the andesite into the slate, though this has been doubted by some. Fig. 44 shows the situation in an E. to W. section.

In the region of Boitza the eruptive zone (predominantly of quartzose dacites or porphyries) crosses an exposure of Mesozoic limestones and melaphyrs, and the veins pass directly from the porphyry into the underlying melaphyr.

At Nagyag, Magura, and Füzesd, in following the gold-veins in depth, masses of Tertiary sandstones and conglomerates are formed, broken through and enveloped by the eruptive rocks.

At four places in the Dacian gold district—namely, Offenbánya, Faczebaja, Fericiel, and Nagyag—telluric ores occur. In the neighbourhood of Zalatna there is cinnabar, and at several points near Körösbánya there are copper-ores carrying a little gold. Gold is, however, mainly connected, as has been observed, with the four ranges of Tertiary eruptives, and appears chiefly in these rocks, though also in the stratified rocks which they traverse.

The occurrence of gold in this case is thus somehow related to the eruptions; but as it has not been found as a primitive or idiogenous constituent of these rocks, it is not to be supposed that it was derived originally from them. There is, therefore, nothing left but to consider the eruptions as the agents of a communication with the deep region, from which at these points the mineral springs ascended. The Dacian gold district will furnish, upon further explorations, important contributions to the inquiry into the original source of the gold. For instance, if the auriferous character of the veins of Vulkoj should be found to continue in the shaly sandstones underlying the andesite, my view would be confirmed.

The Comstock Lode.—The most thoroughly studied American vein-phenomena bearing on this question are doubtless those of the Comstock Lode. It is not necessary to enter here upon a detailed description. As already observed, the general geological conditions of the Comstock Lode show a strong analogy to those of the Schemnitz district. Only occasional bodies of sedimentary rocks are found, while the principal mass of the whole elevated region consists of a great variety of eruptive rocks, principally of the more recent periods. The altitudes of the more important points above sea-level are about as follows:—

	Feet.
Mount Davidson (the highest point of the region)	7,941
Outcrop at the Gould and Curry Mine (the datum-line for measurements of depth)	6,400
The Sutro Tunnel, at different points, 1,840ft. to 1,865ft. below datum-line	{4,560 {4,535
The deepest point in the Belcher and Crown Point shaft, 3,414ft. below datum	2,986

These figures alone indicate the immense extent of the eruptive material.

The stratified rocks occur in a considerable continuous body at Gold Hill, in the southern part of the district, while in the northern part only a small body enclosed in eruptive rocks is found in the Sierra Nevada shaft.

The several eruptive rocks have been differently defined at different times, according to the changes in petrography and in the methods of investigation pursued. Becker distinguishes: 1. Basalt (B). 2. Later hornblende-andesite (LHA). 3. Augite-andesite (AA). 4. Earlier hornblende-andesite (EHA). 5. Later diabase or black dyke (LDb). 6. Earlier diabase (EDb). 7. Quartz-porphyries (QP). 8. Metamorphosed diorites (MDr). 9. Porphyritic diorites (PDr). 10. Granular diorites (GDr). 11. Metamorphic rocks (M). 12. Granites (G). This classification is based upon careful microscopic examination.

The two principal veins (the Comstock and the Occidental) strike N. to S., and the Comstock has been traced three or four miles, according as its branches are omitted or included in the measurement. The position and the branching of the veins are shown in the sketch-map, Fig. 58, in which the two most important eruptive rocks, the diorite and the diabase, are emphasized by shading, the others being indicated by letters, as in the above list. The diorite forms the foot-wall from Gold Hill to Virginia City. South of Gold Hill metamorphic slates form the foot-wall, and even extend across in part to the hanging-wall side, as does the diorite to the north of Virginia City. Moreover, in one place a dyke of diabase—the so-called "black dyke,"—occurs immediately on the foot-wall.

The hanging-wall is principally diabase, at least in depth. In the upper region it is sometimes covered with other eruptives, most frequently with hornblende-andesite.

On the whole (with variations at some places), the Comstock presents wide, gently-dipping masses, predominantly of crushed and decomposed country-rock, and enclosing large flat "horses" of the same. The filling is, as a rule, saccharoidal granular quartz (sometimes more compact), in which the ores are very finely disseminated. At some points they have occurred concentrated, forming the bonanzas to which the colossal gold- and silver-production of the district is due. The ores are silver-ores (stephanite, polybasite, argentite), with sometimes galena and zinc-blende. The bullion produced from them contains about half its value, or 6 to 7 per cent. of its weight, in gold.

Some of these bonanzas were in the upper region and came to the surface. Others (like the richest one of all, in the Consolidated Virginia and California Mine) were found in the deep region; and it is asserted that they were limited on all sides, without connection with other ore-bodies. This would make them unlike our ore-channels or chimneys, which usually do have interconnection. But it is difficult to conceive of their formation in any other way than upon the hypothesis that in such places more open spaces existed, through which larger quantities of dilute metallic solutions passed and made deposits.

The distribution of the bonanza-areas upon the vein-area is quite irregular; and it has not been possible hitherto to trace any connection between the bonanzas and the petrographic or structural conditions in their vicinity. In form they are equally without any law, as far as has yet been observed. The bonanzas of the Consolidated Virginia and California consisted of a main body and three lenticular masses higher up, which, taken together, have a flat pitch to the north. The bonanza between Belcher and Yellow Jacket, on the other hand, followed the true dip of the vein; while the bonanza in Justice—a mine on the N.W. to S.E. branch, which dips north-east much less steeply than the main lode—shows again a north pitch.

This N.W. to S.E. branch of the Comstock shows a filling different in some respects from that of the main lode, and may be considered as a cross-vein running into the Comstock, or into the black dyke which accompanies its foot-wall.

In the Justice Mine the filling is mostly calcite, with little quartz, instead of quartz with very subordinate calcite, as in the main lode. According to Becker the calcitic filling is characteristic of the whole south-east branch. According to Church, compact crusts of calcite alternate in the Justice Mine with their quartz crusts. This is the only clear report of crustification anywhere on the Comstock.

A comparison of the many cross-sections of the Comstock, published by King, Church, and Becker, and representing, of course, various stages of knowledge of the vein, shows that no normal or average section can be given, because the condition at different points on the strike are so different; and at some places—*e.g.*, the junctions of the branches—developments have not given satisfactorily complete exposures. The sections, Figs. 59 to 63, are given (on a scale too small to show much) merely to illustrate the distribution of the country-rocks. They are reduced from Becker's monograph. In the three northerly sections the foot-wall is granular diorite; in the two southern (Yellow Jacket and Belcher), and along the south-eastern branch, it is metamorphic slate. In the southern portion, the so-called black dyke (according to Becker, later diabase) appears on the foot-wall, and follows the vein beyond the point where the south-eastern branch leaves it. The hanging-wall is diabase, except at the northern end, where diorite becomes the hanging-wall as well as the foot-wall. In the upper region, however, earlier diabase is covered by other eruptives. Diabase is the hanging-wall of the south-eastern branch also; but in the foot-wall of that branch, besides the metamorphous slates, granular diorite and quartz porphyry appear.

So far as the sources of the eruptive rocks can be inferred, they were all (except that of the diorite) on the hanging-wall side of the vein, as were also the mineral springs which subsequently decomposed these rocks. But the ascending thermal waters encountered in these mines were within the vein itself; whence it may be concluded that the ore-bearing solutions came by that road from the deep region, and not, according to the lateral-secretion theory, from the side. In other words, the Comstock ores were not washed from those rocks which have been mined between 7,941ft. and 2,986ft. above sea-level, but from material lying much deeper.

The investigations of G. F. Becker were made at a time when importance was still attached to Sandberger's theory, and the correctness of his method of inquiry was assumed. The matter takes a different aspect when we (quite justifiably) doubt whether the minute metallic admixtures detected by wet or dry analysis were originally in the rock, and acknowledge that they may possibly have entered it afterwards. This is evidently the case with the precious metals in the pyrite of the ore-bearing rock. That this pyrite is a secondary impregnation can be proved with the microscope, and is admitted by Becker also. In my opinion, any eruptive rock may give rise by metamorphosis to the type which we call in Hungary greenstone, greenstone-trachyte, &c., and which F. von Richthofen named propylite, because of its frequent occurrence as the country-rock of ore-deposits. Whether the precious metals can be detected in this rock depends wholly upon its impregnation, or that of one of its constituent minerals, with pyrite. But it does not follow that this was the primitive condition. From this standpoint are to be regarded the metallic values reported by Becker, and here reduced, for the sake of better understanding, from cents per ton to grammes per 1,000 kilogrammes. A pyrite washed from decomposed diabase, near the face of the north branch of the Sutro Tunnel, contained 3 cents silver and 8 cents gold—*i.e.*, 0·72 grammes silver and 0·12 grammes gold—per metric ton. The pyrites from the slates in the Belcher Mine carried even 4·32 grammes silver and 0·30 grammes gold. Fresh diabase is said to have contained 0·6 to 0·7 grammes of gold; the diorite of Bullion Ravine, only a trace; while the andesite yielded about as much as the diabase. Augite separated by Thoulet's method from the diabase was found to be eight times as rich as a corresponding quantity of the feldspar.

Comparative investigations are reported to have shown that the decomposed diabase contains only half as much silver as the fresh—a circumstance which was interpreted in favour of the lateral-secretion theory, on the assumption that the decomposed diabase had given up half its silver to the vein-filling.

Since the diorite in the upper portion of Bullion Ravine shows only traces of silver, but at the mouth of the ravine, near the vein, contains a considerable amount, Becker considers this indicative rather of an impregnation of the rock proceeding from the vein.

Moreover, the andesites and quartz porphyries also contain small amounts of silver; whilst the strongly calcareous metamorphic diorite carries 1·92 grammes per ton, which might be connected with the vein-filling in the Justice Mine. Finally, the basalt contains nearly as much silver as the older diabase; but the basalt cannot be cited as a source, because it comprises the freshest rock in the district, and shows no trace of decomposition in its olivine. These facts would be favourable to the notion of lateral secretion, if only it could be proved at the same time that the metalliferous character was primitive. But our knowledge does not go so far as that; and the Comstock, like the deep mines of Przibram, ceases, therefore, to be a proof of the lateral-secretion theory.

The Comstock differs in many respects from typical ore-veins. It is properly a quartz vein in which, at various points, important ore-concentrations have been formed, not showing (except in the Justice Mine) any clear crustification, though this may have been present at some time, and may have been obliterated by metamorphosis of the vein-mass—*e.g.*, through the replacement of calcite by quartz. It is also, in the main, a contact-vein, between a diorite foot- and a diabase hanging-wall, with steep spurs running upward into the diabase and traversing also still more recent eruptives. Some of these peculiarities are represented in other districts.

2. Ore-deposits in Soluble Rocks.

In this group we shall find two genetic types represented—the fillings of spaces of dissolution, and the metasomatic deposits, the origin of which will be particularly considered, together with some related metamorphic deposits in soluble rocks which have not yet been sufficiently studied to be classed apart.

The expression "soluble rock" is to be understood in its ordinary sense of solubility in the waters commonly represented on the earth's surface. Acid and caustic waters will attack, more or less, nearly all rocks, though not so as to dissolve them completely, as we see limestone dissolved. We include especially among the soluble rocks, rock-salt, gypsum, limestone, and dolomite.

Rodna.—The ore-deposit of Rodna, in N.E. Transylvania, is interesting to me (apart from analogies which it offers with Leadville, Colorado) as the first to which my study of the origin of an ore-deposit by replacement was directed.

It is situated on the line of two andesite ranges, having a common strike—the Hungarian Vihorlat Gutine, stretching N.W., and the Transylvanian Hargitta Range, running S.E.—and at the point where this line cuts through the mass of the Rodna Alps. The predominant rock is mica-slate, with numerous intercalations of limestone, and is traversed by many dykes and masses of andesite. Ore-deposits have been found at many points in the district. The most important, situated in the Benyes Mountain, was carefully studied by me in 1862, after the ore-bodies in the mine had been worked out. J. Grimm had examined the mine in 1834, and had considered the deposits to be primitive beds at the contact between limestone and mica-slate, and to have occupied that position before the andesite eruption, by which they had been much shattered.

The ores (pyrites, black zinc-blende, and argentiferous galena, slightly auriferous, with quartz and calcite) often occurred, it is true, on the gently-dipping contact-planes; but in certain E. and W. lines they stood steeply, much like veins. In these places the flat deposit, and with it the

stratification, had suddenly turned upward, and it was clear to me that the occurrence represented a peculiar form of fault—namely, a bending of the strata—followed by fracture in the direction of the dislocating force when the limit of cohesion had been passed. Here and there in these steep places the stopes had been carried beyond the contact, and the resulting appearance was as if the steep deposit had been the primary one and had supplied the ore to the contact. Occasionally eruptive breccias were observed along the steep deposits. At lower levels, in the downward continuation of the fissure of the steep deposit, eruptive rocks and thin breccias occurred; and these became predominant in the lowest part of the mine.

The structure of the ore-beds was mainly massive, and not crustified. In some places, however, druses had been developed, which showed the same paragenetic succession as the mass of the bed, and which contained pseudomorphs of pyrite and galena after calcite. The thickness of the ore-bed was extremely variable, the greater part of the contact-area being scarcely worth working, while at single points colossal masses of ore were found. These circumstances led me to consider the deposits, not as contemporaneous in origin with the rock, but as subsequently formed by the circulation of mineral waters along the contact-planes.

Mining was then active chiefly on the north slope of the Benyes Divide; and the sedimentary rocks were cut off towards the south by andesite. It was pointed out by me that on the south slope, beyond the andesite, there were various ancient mines that could be explored in depth by means of an adit. This led to the discovery of several deposits, which gave new life to the industry. After cutting through the andesite the explorers found steep deposits at the contact of andesite and limestone, and, in the limestone, near its contact with the mica-slate, a flat deposit which, being above the ground-water level, had been transformed into carbonate of lead.

The somewhat complicated conditions are shown in Fig. 70, as far as this can be done in a single section. The deposit at the contact of andesite and limestone indicates at once a genetic connection with the eruptive rock, and renders it probable that the ore-beds also are due to the after-effects of the eruption. Even on the north slope there were some reasons for this conclusion. For instance, at the ore-bodies locally called *thonstrassen*, ores occurred in the midst of eruptive breccia, which could not be taken for fragments of the original bed. Baron Constantine von Beust found traces of "ring-ores," indicating a formation in open cavities.

Seeking an explanation of all the facts led me to give up the view of J. Grimm, which he, however, still maintained, citing Offenbánya as another instance in which a pre-existing deposit on the contact between limestone and mica-slate had been shattered by an andesite eruption. But in that instance also an opportunity was afforded me to satisfy myself that the then accessible mine-workings showed no fragments of an earlier ore-deposit, but only ore-formations under the influence of the andesite.

Grimm had had in mind the deposits of Rodna and Offenbánya when he established, under the first division in his systematic classification, the second subdivision, "Occurrences of Ores as Fragments of Earlier Deposits in Breccias," &c.

Offenbánya.—Offenbánya, in the Transylvania gold district, has various deposits analogous to those of Rodna, and also veins, with telluride ores. We are here interested in its mass-deposits, at the contact of limestone and andesite, one of which is illustrated in Fig. 71.

Beneath the limestone widely extending through the district mining has disclosed a mica-slate (the so-called underground slate), and at the contact of the two a flat pyritous deposit. The whole stratified series is traversed by andesite; but near its contact with the limestone a steep, rich mass-deposit extends from the surface down to the mica-slate. This deposit is highly crustified, and was evidently formed in a pre-existing space.

The flat deposit shows no crustification, and may have been formed by metasomatic replacement of the lime at the contact between the impermeable and the soluble rock. The analogy with the conditions on the south slope of the Benyes Mine, at Rodna, is evident, though it is not certain whether, at Rodna, the flat deposit has been followed as yet to its junction with the steep one.

Rézbánya.—Rézbánya in South-east Hungary represents different conditions. Here, in an indistinctly stratified Mesozoic limestone, occur long spaces filled with ore, descending steeply and irregularly in shape like that of the cavity produced by pouring a stream of warm water upon a snow-bank. This extreme case is of great theoretical interest, although such ore-bodies, having but one considerable dimension, and that in the most unfavourable direction for mining, mainly downward, are not attractive from a commercial standpoint.

In the Rézbánya region, lying above clay slates and Permian and Liassic sandstones, appear numerous isolated bodies of limestone, indicated by their fossils to be of various ages, from the Lias to the Neocomian, seldom distinctly stratified, and, when they are traversed by eruptive rocks, often showing a crystalline structure. The ore-filling is mostly confined to the neighbourhood of the eruptives, and sometimes to the contact, where garnet-rock occurs as a well-known product of local metamorphosis. Since my examination there may have been in this region many interesting and scientifically important developments which are unfortunately unknown to me. It will therefore be necessary to confine myself to the description of a single district, cut off from commercial communication, that of Valle Sacca. The name is that of the valley which heads in a high mountain range of Permian and Liassic sandstones, and, after a short course, ends in a wild limestone cañon leading into the Galbina Valley. The sides of Valle Sacca consist chiefly of limestone, which is traversed by a number of eruptive dykes and one larger mass of syenitic character. Fig. 64 gives a somewhat generalised section of the north-west slope of the valley and district on the line of the so-called fourth adit. At the adit-mouth is cut the syenite mass, which extends also to the opposite slope; and the adjoining portion of the limestone has been metamorphosed to a crystalline mass, while the limestone further south-west is for the most part still compact. On the west side the limestone adjoins sandstone along a N. to S. line, which doubtless represents a large fault. Approximately parallel to it run the greenstone dykes, which,

though they seem to be mutually parallel, in reality intersect one another at very acute angles, thus constituting a highly elongated network. The dykes are not alike. Most of them may be considered aphanitic or dioritic; one, however, is quartz porphyry, with dihexahedra of quartz of pea-size.

The principal deposit is the so-called Reichenstein stock, which had been worked, during the period prior to my visit, to a depth of about 1,300ft. from its outcrop, 1,120ft. above the deepest adit, to a level 240ft. below the adit. Fig. 65 shows the form of the ore-channel on the strike. The horizontal section of the body was most frequently circular or elliptical. In some places one dimension strongly predominated, so as to give the appearance of a fissure-filling. At the outcrop, according to the old maps, there was but one channel; below, this divided into neighbouring and mutually connected branches. Several of these might continue parallel and independent for considerable distances. The total sectional area of these channels averaged perhaps 215 to 322 square feet, but at some levels the deposit was only present in traces, whereas at others it had many times its average section. Fig. 66 shows, by the difference between the plumb-line and the arrow, the angle between the true dip and the pitch of the ore-body oblique to it.

The ores were doubtless sulphides originally, but were afterwards oxidized in places. Rich silver-ores predominated, especially argentite, pieces of which weighing several pounds appear to have been no rarity. Besides this mineral there were hessite (telluride of silver), tetrahedrite, redruthite, galena, bismuthinite, and various pyrites. Taking these together with the oxidized ores the deposit represented a whole mineral cabinet. The maximum silver-value was reported as 12 to 20 kilogrammes per 1,000 (1·2 to 2 per cent.), the gold being 3 grammes to each kilogramme of silver. The percentage of lead was about twenty times, and that of copper about ten times, as great as of silver. The metric ton (2,206lb.) would yield, at this rate, 24 to 40 per cent. of lead, 12 to 20 per cent. of copper, 386oz. to 643oz. troy of silver, and 1·15oz. to 1·83oz. troy of gold.

As regarded the origin of the cavity, my views were influenced by the numerous caves of the region. The mines repeatedly reached caves into which the mine-water could be discharged without filling them, there being some subterranean outlet. But these caves were formed by descending liquids of the vadose circulation; and to assume a similar origin for the cavities filled by the ore-bodies would be to assume that the latter cavities were formed in a manner directly opposite to that in which they were filled, which is highly improbable.

It was not until becoming acquainted with the observations of J. Nöggerath on the thermal springs of Burtscheid that my views were modified by his being able to show that ascending mineral springs are able to cut their own way to the surface, forming the channels which they ultimately fill with ore. The most difficult feature of all—namely, the nearly cylindrical form of the ore-bodies of Valle Sacca—was thus satisfactorily explained.

The channel of the Reichenstein body runs vertically for 1,312ft. in limestone between greenstone dykes; or, in other words, in a zone of lime between two zones of impermeable rock. The dykes therefore control its direction. It follows downward nearly at the angle of their steepest dip, but with a pitch southward, giving it a "false dip."

The sections of the various workings show that the ore-body apparently ended at one side of the dyke, and recommenced at the other side, as if it had passed through. In that case, porous places in the dyke-mass at the intersection will have determined the track of the channel. It is significant that the Reichenstein ore-channel passes in depth through the dykes to the south-west towards what is probably a great fault-fissure, and not in the direction of the present drainage. Nor could the former deep drainage from this channel have been to the north-east, along the contact between the limestone and the underlying Liassic sandstone (which, in fact, appears at a lower level, where the Valle Sacca joins the Galbina Valley), for the reason that all the barriers of the greenstone dykes, unquestionably extending from the limestone into the sandstone, would have opposed that flow. The stratigraphical conditions thus exclude the possibility that this channel was formed by vadose circulation, and render more probable the view that it owes its origin to the ascending waters of the deep circulation, which certainly effected the filling of it.

Raibl.—Raibl, in Carinthia, is the best representative of a group of deposits which were at a recent period taken to be genuine beds even by V. M. Lipold, then the best authority on the mines of the Alps in general. Here and there, as, for instance, by A. Morlet, observations were made which threw some doubt on this conception; but since they did not fit into the prevailing system they remained disregarded. It was my fortune to establish the truth of the situation. Professor von Groddeck kindly characterized my investigation of it as "opening a new path," and adopted the filling of spaces of dissolution as a class in his system.

Such deposits occur in Carinthia, in an E. to W. limestone alpine range, of which Raibl is the western end; and also somewhat further north, in the zone of Bleiberg, near Villach, chiefly in a limestone, early denominated for this reason the ore-bearing limestone, and more recently determined as Triassic.

The ores occurred mostly in the vicinity of certain intercalated slates, which seemed always to occupy the same "Raibl horizon," and thus led to the conclusion that the ore-deposits (naturally believed to be of contemporaneous origin) likewise occupied a fixed horizon. But it soon appeared that the slate at Bleiberg belonged to a somewhat different horizon in the Trias, which showed that the impermeability of the slates, as compared with the solubility of the limestone, had had something to do with the ore-deposition, which was a secondary formation in the rocks.

There are found at Raibl, some distance below the slates, in the limestone which conformably underlies them, what seem indeed at first glance to be beds of ore. They consist chiefly of a coarsely crystalline galena, with pyrites, and a zinc-blende (wurtzite) in very thin crusts, hence called *schalenblende*. A closer study, however, of the extremely distinct crustification reveals that it does not represent the stratification, which, on the contrary, it crosses at all angles, being, in fact, the filling of irregular spaces traversing the limestone in every direction.

Further light is furnished by the seams which here occur. As is generally the case in limestone, these are rarely wide fissures, but usually mere partings between two polished walls in close contact. Slickensides, &c., identify them at once as results of friction caused by the forcible rubbing together of walls perhaps originally irregular. The plane of contact with the slates offers a means of determining the extent of the movement along some of these insignificant-looking seams; and it appears that dislocations as great as 131ft. to 196ft. have thus taken place. Since the slates possess some flexibility, they were sharply bent in the immediate neighbourhood of the fault, a feature which, on account of its theoretical importance, is illustrated in Fig 69.

In the seams themselves there can be, of course, no deposit of ore; but such deposition occurs outside of the fissure when soluble rocks like this limestone are traversed. Geode-spaces were thus leached out, and are found filled with distinct mineral crusts, as is shown in Fig. 72, representing the face of a level on the so-called *johanniblatt*.

It cannot be doubted that the ore-supply came from the seams; and when we find such seams also in large and rich deposits of similar character, like those on the north slope of the Königsberg, at Raibl, we must concede to them a similar significance as regards the ore-deposition.

To the more important of these seams J. Waldauf von Waldenstein and Dr. W. Fuchs had already called attention. These are the Morgen, Abend, Johann, and Josef. The first three meet at an angle of 30°, and form the boundaries of ore-bodies extending downwards along the seams, with a horizontal length of 131ft. to 262ft. and a total thickness (including portions too poor to work) of 33ft. to 164ft. Many of the mine-managers believed that there was here a continuous ore-bed which had been faulted into separate bodies by the seams, and numerous exploring levels were undertaken to develop this assumed bed, but all in vain. Nothing was found except a few more or less independent ore-shoots on one or both sides of the seams, similar to those which have been encountered in recent years at Leadville.

The foregoing observations will facilitate a comprehension of Figs. 67 and 68, the former showing a section (not strictly in one plane) of the ore-shoots in the Government mine, and the latter a similar picture of the Struggl private mine. In the former, separate ore-bodies are observed to the distance of 1,640ft. above the bottom of the valley, and in 1870 the continuous ore-shoots extended from 1,394ft. above to 492ft. below that level, a total vertical height of 1,886ft.

It will be seen that the several portions of the slopes descend more or less parallel with the stratification and the lime-slate contact, but with steps or offsets. The highest portion of the Abendblatt ore-shoot is about 984ft. in the foot-wall of the slate-contact; at greater depths there are portions only 426ft., 492ft., 279ft., and finally 33ft. from that plane.

It thus appears that the ore-shoots are approaching the contact in depth, and will probably follow it below. It is, therefore, not here the case that a particular layer in the limestone has favoured the formation of spaces of dissolution. If that were true, the ore-body, notwithstanding the convergence of the seams southward, should maintain a more or less uniform distance from the contact, which it does not do, either in the section of Fig. 67 or in that of the Struggl Mine (Fig. 68) where the opposite occurs—namely, the ore-shoots depart from the contact in depth.

The North of England.—We must not omit to mention here the region, classic in this respect, of the North of England. Lead-mining is actively carried on in the carboniferous limestone of Northumberland, Durham, Cumberland, and Westmoreland, where the limestone alternates with sandstone and slate and occasional intercalated eruptives or their tufas. This formation is traversed and faulted by a variety of seams and veins; and the veins are generally richer where they are in the limestone. The thinner and more extensively faulted of the limestone strata are entirely severed, so that they appear in different horizons on opposite sides of the faulting-fissure. Where they are thicker or less widely thrown by the fault, however, limestone appears on both sides of the latter. It is obvious that an accurate picture of these conditions would furnish valuable data concerning the ore-genesis.

The several descriptions of the mines do not specify whether the ore of such veins as become rich in the limestone occurs in the fissures proper or outside of them in spaces of dissolution in the limestone. The latter is clearly the case in the so-called "flats." In certain horizons, where the seams encounter the soluble lime-stratum, the ore-filling departs from the fissure into the geodes of the rock, forming frequently very rich ore-bodies of highly irregular form, but flat, by reason of their following the soluble stratum. The ore-filling continues to a very uncertain distance from the fracture-plane, and is generally accompanied with frequent cavities, the walls of which are covered with crusts of calcite, blende, and galena. Empty caverns also occur. We cannot but recognise immediately in this description the type as to character and position of the Raibl deposits, the druses of which are here represented by the incrusted cavities. The empty caverns have doubtless been formed by subsequent processes of dissolution.

These phenomena occur in the North of England on a very large scale. Veins are mentioned which have been traced for several miles, and the connected subterranean channels of dissolution must be also of considerable length. The existence of literally extensive ore-channels, and hence of an underground circulation of mineral waters not formerly suspected, is thus revealed, and an entirely new light is thrown upon the so-called "ore-beds."

These observations are confirmed in another quarter by developments in Western North America, where very numerous ore-deposits are connected with limestone, and to certain localities which have been thoroughly studied and described in publications.

Leadville.—We will begin with Leadville, the recent blossom of the mountain world of Colorado. This is a locality the importance of which was not recognised until after my visit to the United States; but my lively interest in it is testified by the article concerning it which was compiled in 1879 from the incomplete data then available. Later, when S. F. Emmons had finished his surveys, but before the publication of his epoch-making work, opportunity was afforded me to exchange views with him concerning the genetic condition, and to confess that my opinion

Fig. 40

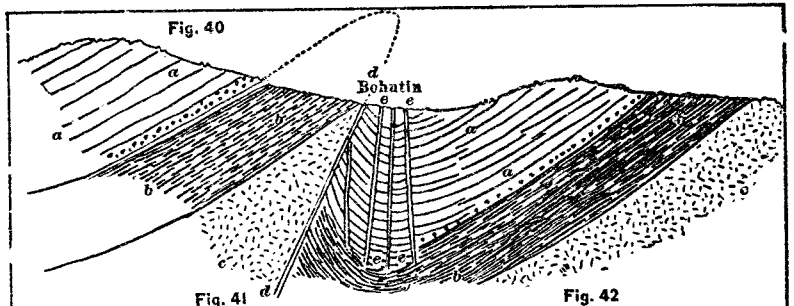


Fig. 41

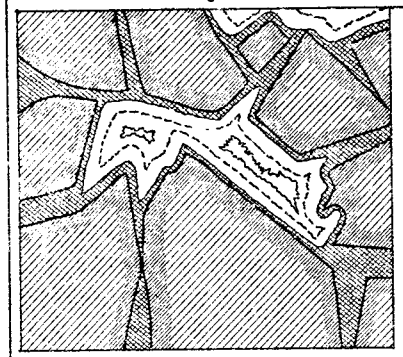


Fig. 42

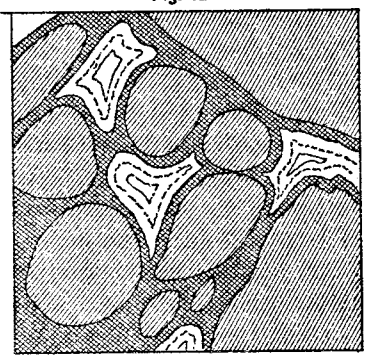


Fig. 43

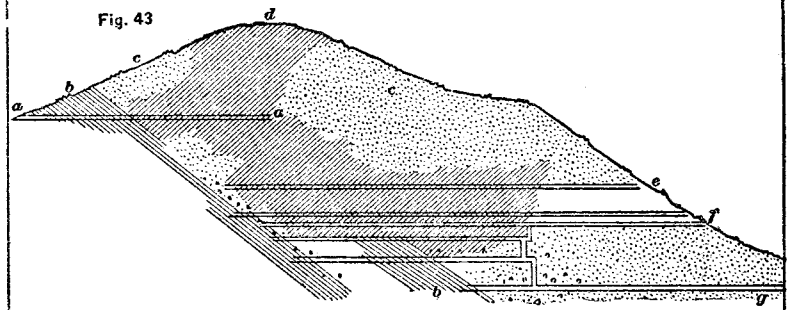


Fig. 44

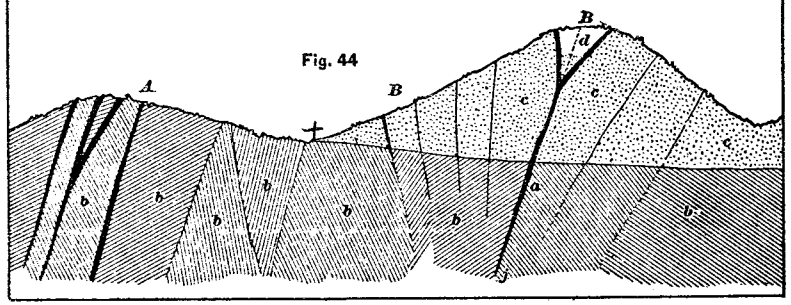


Fig. 45

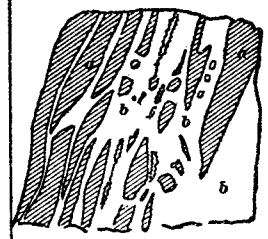


Fig. 46

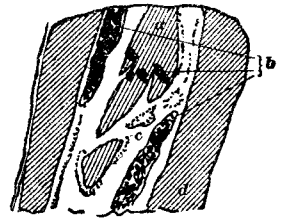


Fig. 47

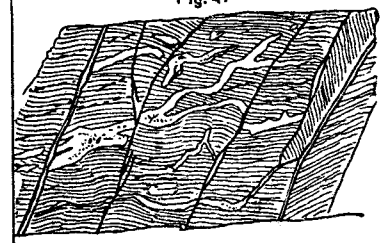


Fig. 48

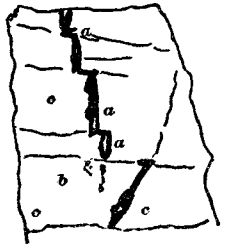


Fig. 49

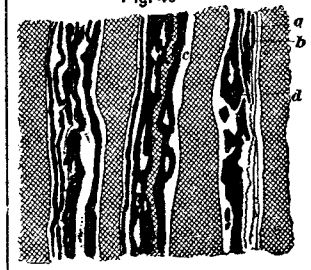


Fig. 50

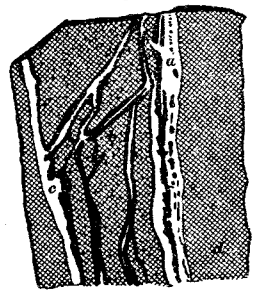


Fig. 51

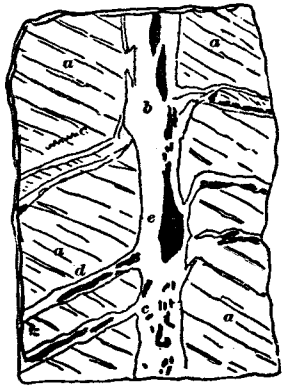


Fig. 52

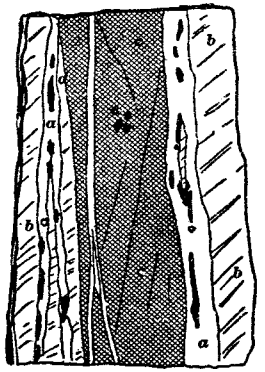


Fig. 53

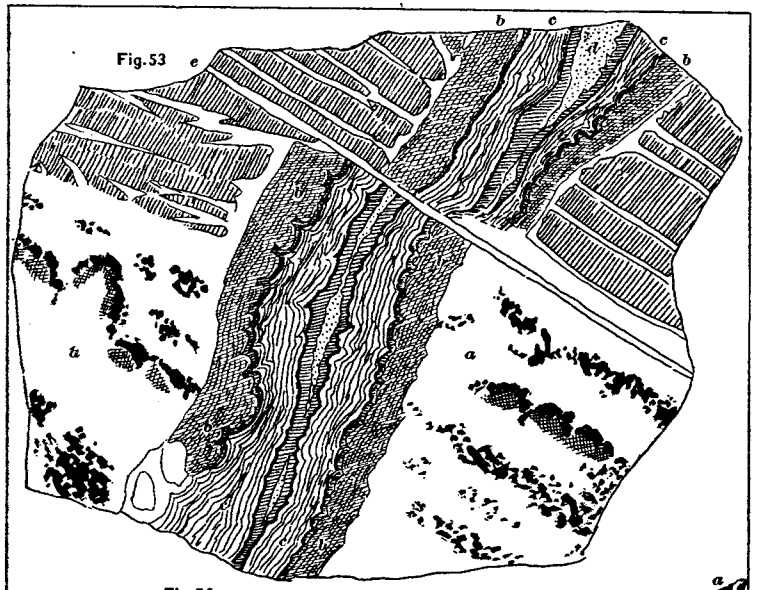
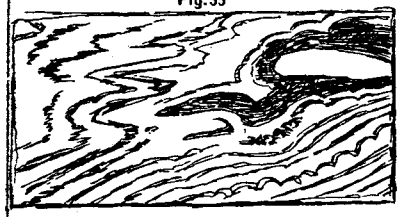


Fig. 54

Fig. 55



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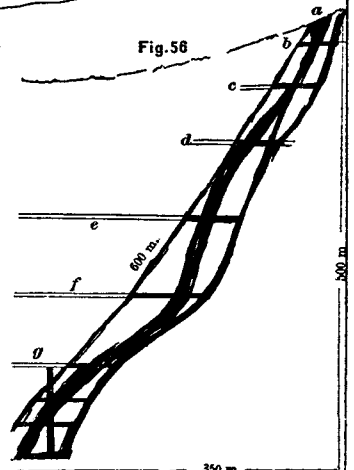

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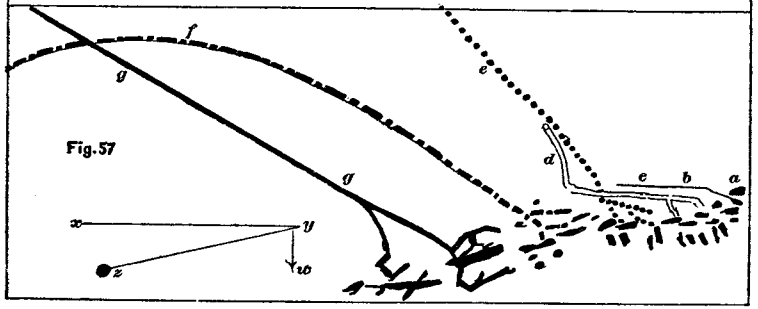

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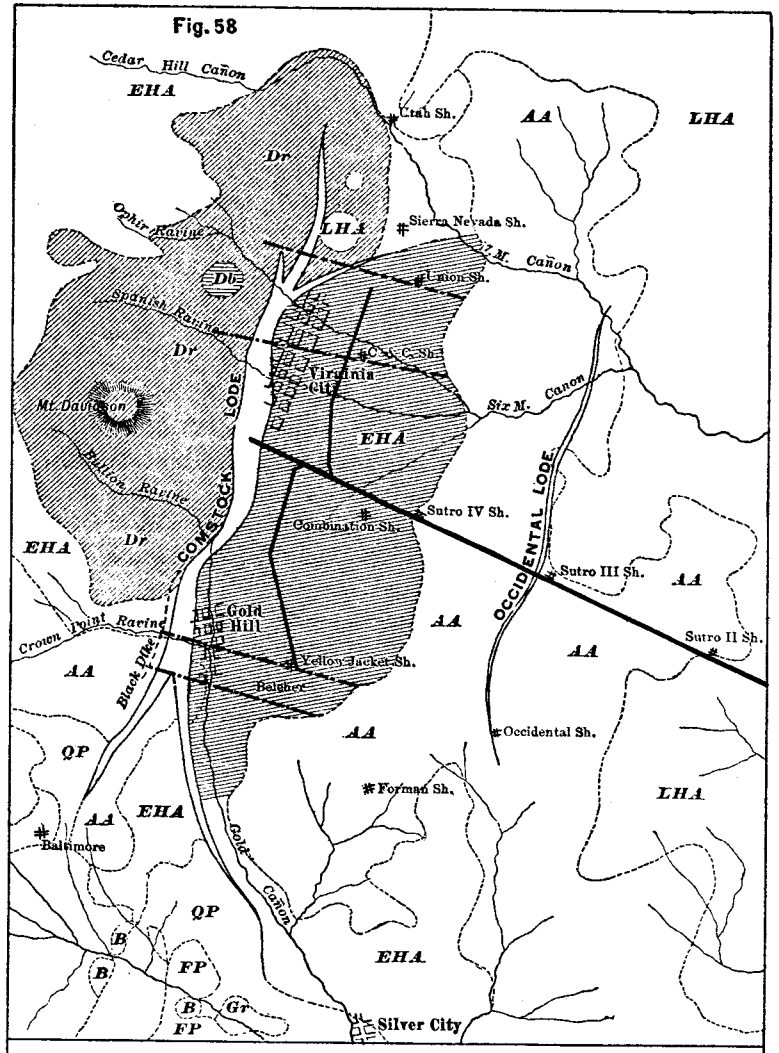

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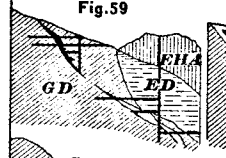
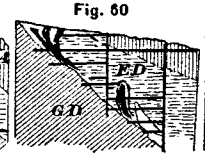


Fig. 60



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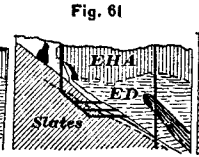


Fig. 62

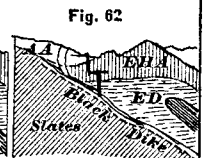
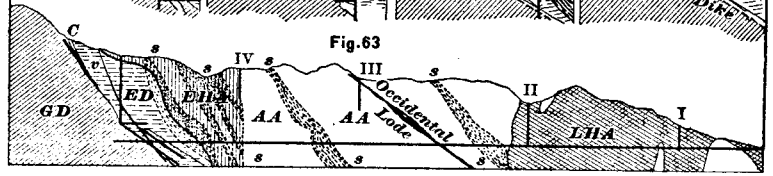


Fig. 63



was at variance with his as to the downward course of the mineralising solutions—an opinion which was opposed to the then prevalent belief. The mine-workings have been greatly extended since that time, and Emmons's suggestion has been shown by several mining engineers, on the basis of thorough studies underground, to be untenable; so that the Leadville deposits appear, as regards the origin of their metallic contents, to form no exception to the history of other similar deposits. Mr. Emmons himself must have acknowledged the force of these criticisms, which do not detract in the least from the merit of his accurate investigation of the district.

On the west slope of the Mosquito Range appears a series of undulating Palæozoic strata, with heavy layers and intrusive masses of eruptive rocks, and traversed by numerous faults. This formation covers a large area, only a comparatively small portion of which—namely, the vicinity of Leadville—is ore-bearing—a circumstance which of itself points to a local origin for the ore. As is well known, the series of rocks has the following order downwards: white porphyry, blue limestone, gray porphyry, white limestone, lower quartzite—which will be denoted, for brevity, by their initial letters. The ore-deposits occur chiefly at the contact between the first two members of the series, below the WP. and above the BL. In the upper levels they are oxidized and chloridized (doubtless in this, as in other places, through the action of descending ground-water); in lower levels they appear in their original form as sulphides. That this was the condition in which they were originally precipitated Emmons admits; only their position seems to him to exclude the hypothesis of ascending solutions. He says, "The principal water-channel at the time of deposition was evidently the upper contact of the blue limestone with an overlying porphyry; and from this surface they penetrated downwards into the mass of the limestone. It may be assumed, therefore, that the currents were descending under the influence of gravity, rather than ascending under the influence of heat."

But he omits to explain how he conceives it possible that mineral solutions descending by gravity, and hence certainly having been in contact with the surface-region, could deposit sulphides. Assuming such an explanation to be furnished by reduction through organic substances, the question arises whither such descending currents could go. Here the theory is in conflict with our conception of the underground circulations.

As A. A. Blow has shown, however, a leaching of the WP. cannot by any means have supplied the ore, for this rock is not at all decomposed, as in that case it must have been. On the other hand, there are found in the intrusive beds and dykes of the lower GP. various indications that this rock had more to do with the ore-deposition. Along these dykes lie the ore-shoots—in other words, the channels in which ore was deposited.

It was at first tacitly assumed that the ore occupied the whole plane of the contact, although it was known that the richest bodies occupied particular zones in this plane. The importance of these ore-shoots was recognised later; and we may now consider the Leadville occurrence as presenting, not a single contact-deposit or ore-bed, but a complex group of ore-shoots, such as we have observed in other ore-deposits in limestone. These ore-shoots lie, in Leadville, at the contact between the soluble and the eruptive rock; while in Raibl they appear near the contact of two stratified rocks, one soluble and the other impermeable. The physical process forming these ore-shoots was doubtless the same in both cases. The mineral solutions, ascending under pressure, and seeking a path to the surface, followed, as some would say, the line of the least resistance; or, to express it, there was established in the soluble rock a line of maximum circulation resulting in the dissolving-out of a channel.

Such dissolution, however, occurred, not only on the contact between WP. and BL., but also at other contacts. Thus L. D. Ricketts gives a section of a mine on Carbonate Hill showing a second deeper ore-horizon between the GP. (dyke porphyry) and the underlying limestone. According to Rolker, the BL. of Fryer Hill was relatively thin, and has been replaced with ore and accompanying minerals, all but small remnants of dolomotic sand. These are generally above the ore—*i.e.*, along the upper contact—whereas, according to Emmons's theory, they should be replaced with ore.

The sections given by F. T. Freeland (*l. c.*, Figs. 1 and 6) show two ore-horizons, the thicker of which is below the WP., and the other below an intrusion of GP.; and Mr. Blow's sections from Iron Hill reveal similar phenomena (see Fig. 73, a section through the McKean shaft). The ore-shoots are, of course, irregular in form; but a main general direction can be recognised, which is eastward in Fryer Hill, but north-eastward in Carbonate and Iron Hill, representing the course of the channel through which the mineral solutions circulated.

In the data at hand concerning the structure of the deposits, nothing is said of a distinct crustification. It is to be remembered, of course, that mining operations hitherto have been largely confined to the upper and decomposed zone, whereas this phenomenon, if ever so fully developed, would show itself clearly only in the undecomposed zone. When we read, however, of great "horses" of country-rock encountered in the midst of the ore, we must believe that the deposit is due not so much to a metasomatic replacement of the limestone as to the filling of spaces of dissolution; and hence it should exhibit the characteristic sign of such a filling—namely, crustification. It seems to me that this point has not received the attention it deserves; and it is to be hoped that observations in the undecomposed ore-zones will give more definite data as to structure. It is difficult to believe that metasomatic processes could produce such pronounced ore-shoots as those described at Leadville.

Impressed by Emmons's views, and long before the connection of the ore-deposition with the GP. of the dykes had been shown, it was doubtful, in my mind, whether the ore might not have come somehow from the fault-fissures into the contact-channels. But Mr. Emmons pointed out to me that the faults contain only ore which has been dragged in from the pre-existing bodies, the formation of which was complete before the faulting took place.

Conditions analogous to those of Leadville are exhibited in most of the ore-deposits in limestone occurring in the American West. But, with few exceptions, we have only hasty descriptions of them, and sometimes nothing more than business "puffs."

Red Mountain.—A remarkable occurrence has been described in the Red Mountain district, Ouray County, Colorado. In the midst of the deposits of the San Juan region, which are connected with eruptive rocks, appears a body of Mesozoic strata, carrying, at the contact of a quartzite with the underlying limestone, a deposit of the sulphides of iron, lead, copper, silver, and the products of their decomposition, rich in silver and somewhat auriferous (59oz. to 111oz. of silver and 0·08oz. to 0·17oz. of gold per ton of 2,000lb.). At certain points the ores extend far down into the limestone, and in the section shown in Fig. 74 the ore follows a fault-fissure through the whole thickness of the limestone into a second quartzite stratum below. The stratified formation is mostly covered with andesite, in which occur ore-bearing veins in fissure form.

In the neighbourhood, at Mineral Farm, another contact-deposit between limestone and quartzite is known, consisting of barite with argentiferous galena and tetrahedrite. Both the above deposits are but briefly described, and perhaps have not been extensively worked. Their conditions of position and the predominance of lead- and silver-ores strangely remind one of Leadville.

In the adjacent territories of New Mexico and Arizona various copper-deposits occur in limestone, and at its contact with eruptive rocks, as, for instance (according to the outline-description of A. F. Wendt), in the Clifton and Bisbee districts. The sections accompanying Mr Wendt's paper remind me of some of the deposits described in my monograph at Rézbánya, at Mědnorudjansk, and at Bogoslavsk, in the Ural. Fig. 75 is an interesting section from the Clifton district, in Arizona, showing two steep ore-shoots, parallel with the felsite dyke, and a flat one, parallel with the bedding.

Utah.—With respect to Utah, the paper of O. J. Hollister gives a general survey of the deposits of the Territory, and mentions a number which occur in limestone. Some of those in central Utah an opportunity was afforded me to see personally, during the period when mining was still confined chiefly to the decomposed upper levels.

Palæozoic strata are here traversed by frequent eruptive dykes, and by two intersecting systems of faults. The ore-deposits, of varying thickness, in the limestone have, as a rule, the form of "chimneys," either lying flat with the bedding or standing steeply along the dykes and faults. This gave rise in the beginning (when the nature of the deposits was not understood, and the conception of a typical "lode" generally prevailed) to a series of disappointments and mistakes in mining, of which the history of the Emma Mine furnishes an interesting example. Apparently the irregularity and the complications of these deposits came to be better known afterwards.

The (sometimes very rich) ores consist chiefly of sulphides of lead and silver, and the products of their decomposition. In some cases (*e.g.*, Hidden Treasure) cuprite occurs, with native copper; and in the Camp Floyd district cinnabar also is found.

Nevada.—In Nevada, adjoining Utah on the west, deposits of this class are likewise abundantly represented. The two districts which have been most thoroughly studied are White Pine and Eureka.

With regard to the former, the work of Arnold Hague (1870), demonstrating the peculiar character of the White Pine deposits, led me to seek for European analogues. It was found that, apart from the condition of the ores, which at White Pine are found in the oxidized and chloridized zone, there was an analogy with all the European ore-deposits in limestone, but especially with the conditions at Raibl.

Devonian limestones and calcareous slates are overlain at White Pine by Carboniferous clay-slates, sandstones, and limestones; and the ores occur only in Devonian limestone and at its contact with the calcareous slates on a north and south anticlinal. The ores and the associated minerals (quartz, calcite, gypsum, fluorspar, barite, rhodonite, rhodochrosite, with the chlorides, bromides, oxides, and carbonates of various metals, especially silver, lead, and copper) fill the cavities in the limestone and surround its fragments.

The various mines represent different stages in one and the same process. In the Eberhardt, two fissures crossing the anticlinal bound the ore-body (like the Morgenblatt and the Abendblatt at Raibl). This consists of a lime-breccia (Kalktyphon), the fragments of which fit together, and are cemented by ore-bearing quartz seams. The Hidden Treasure Mine contained the ore in geodes, at the contact of the limestone and slate. In the Aurora, the ore was in bodies stretching north and south. In Bromide, Chloride, and Pogonip Flats, the ores occurred in geodes and masses included in lime-breccia, in a zone parallel with the bedding. It is Arnold Hague's opinion that the Eberhardt Mine probably represents the source of the ore-solutions which impregnated the limestone, wherever cavities existed, up to the level of the overlying calcareous slates, which were impermeable to the solutions. The slate cover having been removed by erosion, the ores thus accumulated below it were exposed immediately at the surface; and the surprisingly large product of the district was derived from open cuts and shallow workings.

The other leading analogue in Nevada is found in the Eureka district, and was made widely known and practically significant by the law-suit between the Eureka and Richmond Companies, which involved the definition of a deposit not contemplated in the United States mining law. Similar difficulties have arisen under the old European mining codes. Such deposits were known in some districts of Europe, but they were not so widely distributed as the fissure-veins, for the conditions of which the ancient codes were framed. Conflicts were therefore inevitable. In Bleiberg in Carinthia (which presents some degree of analogy with Eureka), besides the general mining code, special statutes became necessary, departing from the usual rules with regard to prospecting and the location and the acquisition of claims.

According to Arnold Hague, the series here occurring of Prospect Mount quartzite, Prospect Mount limestone, Secret Cañon shale, and Hamburg limestone, is Cambrian. The ore is confined to the limestone first named, and in particular to a portion thereof on the north-east slope of Ruby Hill, enclosed between two fault-fissures. The features of the N.W. to S.E. ore-bearing zone are too variable to be indicated by a normal cross-section. Fig. 76 shows a generalised and Fig. 77 an actual section as represented by Curtis.

The main fault-fissure separates, in the upper level, the massive limestone in its hanging-wall from the crushed ore-bearing limestone in its foot-wall. In the lower levels it shows, in the foot-wall, quartzite with intercalated "lower shale," and in the hanging-wall, further down, shale and quartzite. An ideal restoration, above the present saddle of Ruby Hill, of the foot-wall rocks which have been removed by erosion would bring to light a relative displacement of 492ft. to 1,968ft.—the indications being that the foot-wall has been lifted. This would explain at once the crushing of the limestone in the foot-wall, and the creation of a second fault near the contact between the limestone and the underlying quartzite.

The ores occur chiefly in the well-known forms of chimneys and in individual masses, mostly interconnected by traces of ore, at least at the depth where the two faults come together. In the mines to the south-east, about 590ft. from the Eureka-Richmond boundary, the fissures come together at the depth of about 1,312ft., the line of their intersection thus dipping gently north-west.

The ores encountered in the upper zones, above water-level, were, with the exception of a few insignificant remains of sulphides (mostly argentiferous galena), oxidized ores, such as cerussite and anglesite, chlorides, &c., carrying a considerable amount of silver and a little gold. The present water-level follows approximately the line of intersection of the two faults, but the fact that oxidized ores have been found still deeper indicates that the water-level was once lower down.

It might consequently be expected that caves formed by the vadose circulation would also occur at considerable depths, especially as the whole wedge of limestone is traversed by ore-shoots, the oxidation of which would, of course, give occasion for cave-formations. The newly-formed caverns would often lie along the ore-channels, and especially in their upper portions.

Some of the irregularly-distributed ore-bodies follow rather the quartzite-limestone contact; others rather the main fissure, with a north-west dip, like that of a limestone wedge. Of the two largest bodies which have furnished the chief product of the district, the east ore-body exhibits a steep south-east pitch for nearly 1,312ft., and the west ore-body, for nearly an equal distance, a flat north-west pitch.

In considering their structure, we must distinguish sharply between their original and their decomposed condition. The latter often hinders a clear recognition of the former. The strata-like deposits of cerussite and other products of decomposition mentioned by Curtis are perhaps like those in my sketch (Fig. 78), from the old Telegraph Mine—remains of the original classification; and his statement (page 104) that "when the ore is not oxidized there are no signs of a banded or concentric structure, and the phenomena observed point entirely to substitution of the sulphurets for country-rock," may thus be explained. In like manner, his assertion, in the same place, that "the internal structure of the ore-masses in no way resembles those of Raibl," is so far correct that the original filling is at Raibl extraordinarily distinct, and at Eureka, on the contrary, perhaps only obscurely traceable.

In the Eureka Mine were some small ore-masses which exhibited crustification, if not in a striking degree, yet sufficiently to be recognized by an impartial observer. Mr. Curtis himself says that "rounded boulders of limestone as a nucleus" occasionally occur in the ore-mass, and that in a limestone-breccia "small masses of ore sometimes completely fill the spaces between the limestone walls,"—two phenomena which indicate crustification, and are explained by the hypothesis of a filling of pre-existent spaces.

A metasomatic removal of the limestone, such as has taken place in the secondary calamine deposits of Raibl, cannot well be supposed for the original ore-deposition at Eureka, but may have attended the formation of the secondary decomposed products.

Later mining in deeper zones has developed more clearly the structure of the original Eureka deposits, and that specimens of the ore have shown, after polishing, traces at least of crustification. In short, the original Eureka ores have been deposited in pre-existing spaces by ascending mineral solutions, while their decomposition and the formation of the caverns are the effects of descending surface-waters.

Missouri and Wisconsin.—We have dealt thus far with ore-deposits in mountain districts, where tilting and folding, as well as the occurrence of eruptives, betray a disturbance of the original relations of stratification. But there are also deposits in limestone in plateau regions, where the strata show no considerable disturbance. Under this head two great districts deserve attention—namely, the lead-regions of Missouri and Wisconsin.

Concerning the former, we may refer to a number of more or less detailed descriptions.

We have in this case not a perfect plateau, since here and there domes of the underlying Archæan come to the surface, as especially in the continuation of the Ozark Mountains; but the predominant character is nevertheless of a structural plateau. The ore-deposits, chiefly confined to the Silurian limestone, are in part primary xenogenous and in part hysteromorphus (*débris*) deposits; the latter, as is well known, consist of the detritus from the weathering and erosion of the outcrops of the former. In the former, we find all the phenomena encountered in the deposits of mountain regions. One of these is peculiarly developed—namely, the gently-inclined cavities or ore-channels, shown in the Vallé and Bish mines of Jefferson and St. Francis Counties, concerning which J. R. Gage has given some (unfortunately not very clear) notes and sketches.

In the Vallé mines, a shaft 164ft. deep, situated 110ft. above the valley bottom, encountered at three different depths, respectively of 146ft., 151ft., and 164ft., flat-lying ore-channels, 3ft. to 6ft. wide, which, winding in different directions, produce networks, connected at the intersecting points by chimneys from one level to the other. The cross-section of these channels in the horizontal limestone or dolomite contracts sometimes to a few square inches, or enlarges to several square yards, with a height of 10ft. to 12ft.

The original metallic filling was galena, pyrite, and zinc-blende, but is already oxidized to cerussite, anglesite, smithsonite, and calamine, which are accompanied with barite and a red clay. We are specially interested in the original structure of this filling; but this is not easily detected in the mere diagrams at hand.

Figs. 32 to 35 reproduce four of Mr. Gage's sections, the first three being Figs. 17, 18, and 19 of his paper in these "Transactions," and the fourth, Fig. 72 of his article in the report of the Missouri survey. They indicate for both the metamorphosed and the original mineral crusts a prevailing horizontal position, so that we might conclude that the deposits took place in cavities, the upper portions of which were filled with gas only. A very peculiar formation is the red clay which in some instances covers the walls of the caverns and surrounds on all sides the central filling. The data at hand afford no clue to its origin.

Mr. Gage's description of Fig. 35 is as follows: "Fig. [72] represents the occurrence of these minerals. The solid limestone contains a fissure, entirely filled with minerals and gangue. The minerals are completely enveloped by the red clay. Above are two thin folds of silicate of zinc, separated from each other and from the limestone by the red clay. The folds of the zinc-ore are sometimes perfectly solid, being from 1in. to 6in. thick, and consisting of alternate layers of the same material in very compact folds; again, the mass of zinc-ore is from 1in. to 6in. in thickness, but, instead of being dense, consists of a thin crust, with a cavity, whose interior walls are lined with beautiful brilliant crystals of the silicate, and occasionally the carbonate of zinc. More rarely, crystals of galena are in the cavities, but, in this case, are invariably covered with a thin coating of the silicate; and not infrequently portions of the cavities are partially filled with red clay, highly impregnated with oxide of iron, and having the appearance of a highly-decomposed brown hæmatite. Occasionally, heavy spar (barytes) lies in a dense mass in close contact with the zinc-ore, but more frequently it is associated with the galena. Often, but not invariably, immediately below the folds of zinc-ore occur irregular masses of the zinc-ore in the crystallized form, as pseudomorphs of galena," &c.

All the doubts which arise concerning the mode of this formation would probably be solved by a series of *objective* pictures of it; and it is to be hoped that an occurrence so interesting theoretically will be accurately recorded before it is too late.

The deposits occurring near the "islands" of granite and porphyry have special interest. While the Silurian limestones of the surrounding country, farther from these islands, present chiefly only lead- and zinc-ores, other metals, such as copper, cobalt, and nickel, occur as the Archæan foundation-rocks are approached; and this circumstance is, to my mind, an indication that the source of the lead-deposits also is to be sought in depth.

Mine la Motte.—The rock here is usually the same—namely, a Cambrian dolomite, containing, however, sandy portions and a clayey stratum characterized by numerous fossils (Lingula). The ore occurs predominantly as an impregnation in the rock, more concentrated in a given zone. The so-called sandstone does not here, as in other instances, cut off the impregnation; it is, in fact, only a sandy limestone and dolomite, and its carbonates can be replaced by ore as well as those of adjoining strata.

In the open workings called the Jack and the Seed-tick Diggings a very remarkable phenomenon occurred—namely, the ore-impregnation in the almost horizontal stratified rock was conformable not to the bedding, but to planes crossing it at a very acute angle (about 10°). A pretty long terrace was exposed; and the impregnation-planes cut pretty regularly through the sandy dolomite also. This appearance indicates plainly a later formation of the ore, independent of the deposition of the rock-strata; and one is almost involuntarily forced to believe that it was the former ground-water surface which formed the cavities to be impregnated. But it was, and is, inconceivable to me how these cavities could be filled with sulphides.

Wisconsin.—In Wisconsin, and in parts of Iowa and Illinois, there is an extensive true plateau the calcareous members of which contain many and various deposits of lead- and zinc-ores. An excellent monograph concerning them, by my esteemed friend, Professor J. D. Whitney, is at hand. The author seeks to show that the mineral solutions depositing these ores came from above, not from below. He appeals to the circumstance that, of the two stratified formations, the upper and the lower Magnesian limestone (underlain by an upper and a lower sandstone respectively), the ores occur chiefly in the upper, and only seldom, and in small quantity, in the lower; while the two sandstones, the lower of which is assigned to the Potsdam, do not reveal any traces of ore, as they should do if the solutions had come from below. There may have been a passage through these sandstones at a distant point, not yet exposed; and the mineral solutions may have found or created spaces in the soluble rock.

The argument that the ores must have come from above because it has not been possible to discover, in the Wisconsin region, fault-fissures and eruptive dykes such as have brought up similar ores in the north of England and other places seems to me likewise inconclusive, and cannot be accepted by me as the explanation of an occurrence near Dubuque, discovered by T. Lavins and described by Whitney. The fragments of galena, crusted with cerussite, which hang from the roof of a natural cavern, are taken as a proof that the solutions which deposited them must have come from above. But a continuation of this cavern is indicated in the bottom, filled with clay, mixed with scattered pieces of galena. In my opinion, this was doubtless originally the filling of a vertical fissure, which was enlarged by the ground-water, as indicated by the dotted line. The symmetrical crusts of that filling were in part broken up, and fell into the clay accumulating in the space below, while the upper part of the filling remained attached to the rock of the roof.

3. Metamorphous Deposits.

Metamorphism has been most truly defined by A. de Lapparent as the sum of the chemical changes undergone by the sedimentary rocks after their deposition. General or regional metamorphism, affecting the rocks over wide areas, is distinguished from local or contact metamorphism, caused in certain groups of strata by eruptive intrusions. In studying the occurrence of useful minerals, we occupy rather the local standpoint, and start with an assumed original condition of the rock, though its really original character may not always be demonstrable—understanding thereby, for our purpose, a so-called typical condition, usually shown at most places where the rock occurs.

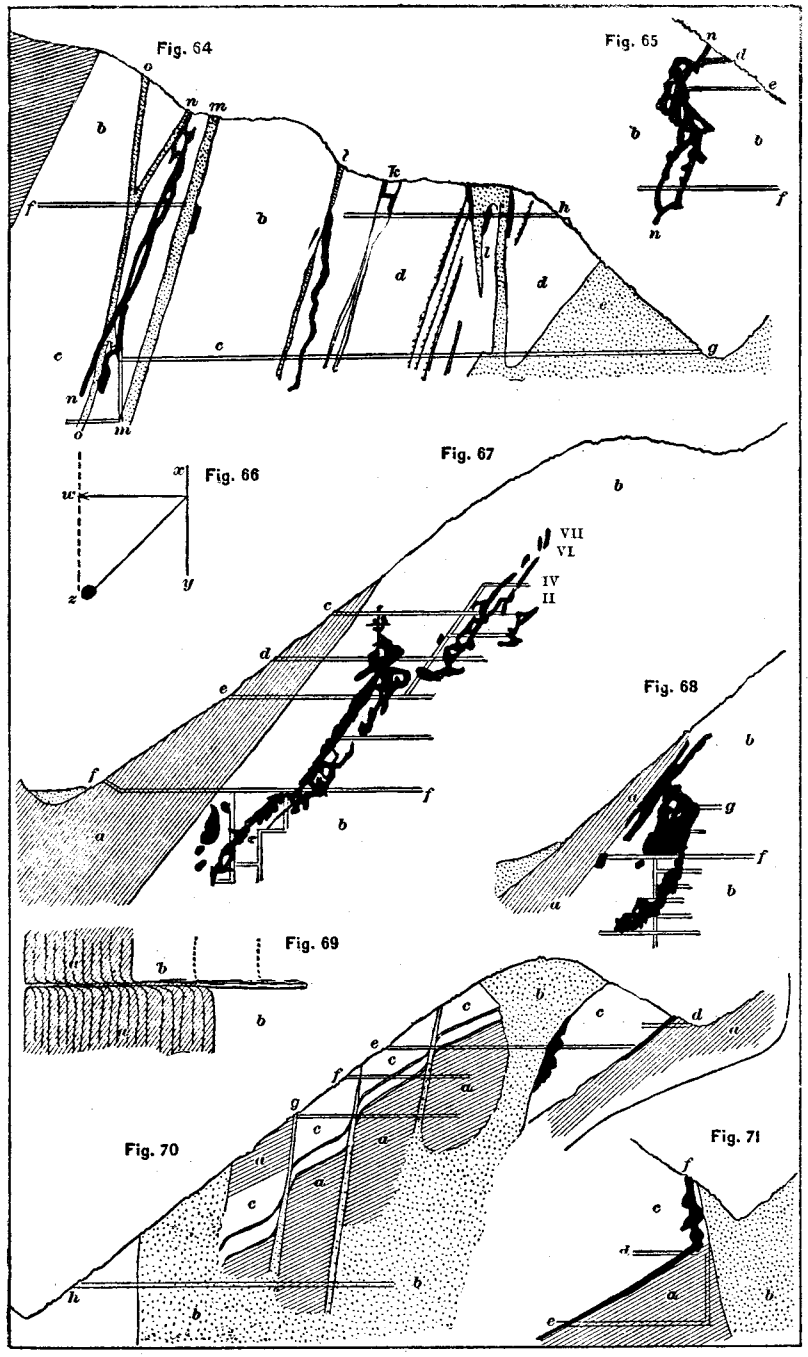

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Fig. 65
Fig. 66
Fig. 67
Fig. 68
Fig. 69
Fig. 70
Fig. 71

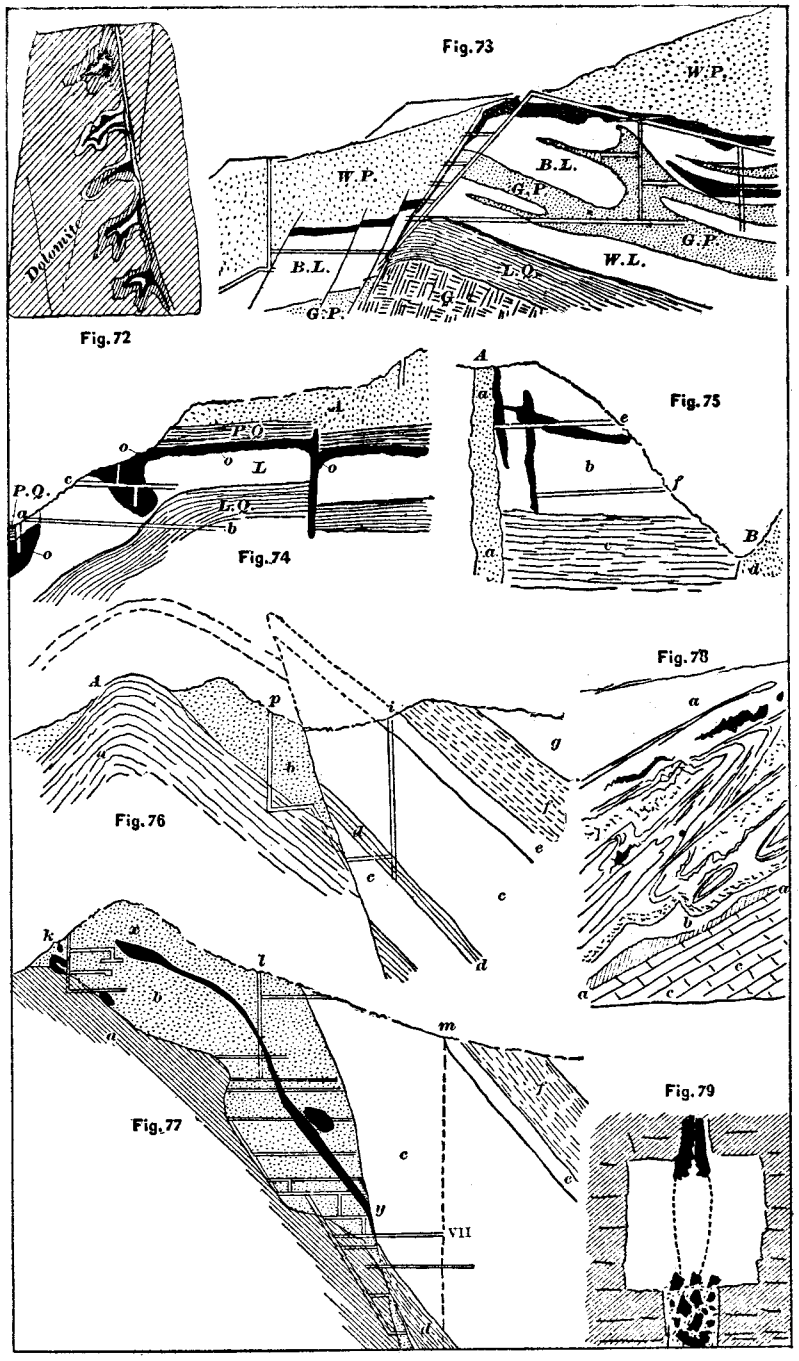
Fig. 72
Fig. 73
Fig. 74
Fig. 75
Fig. 76
Fig. 77
Fig. 78
Fig. 79

Fig.80

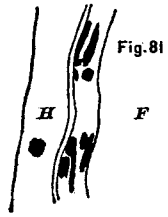

Fig.81

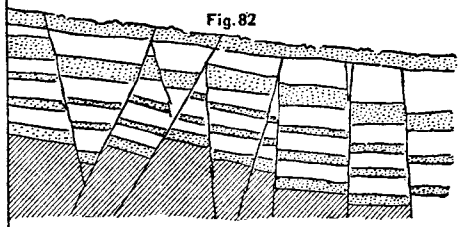

Fig.82

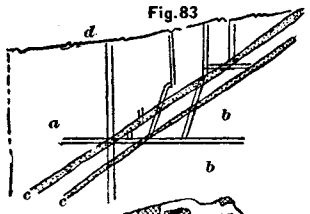

Fig.83

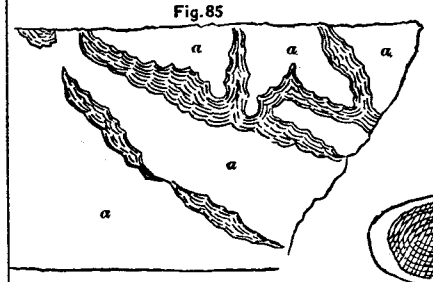

Fig.85

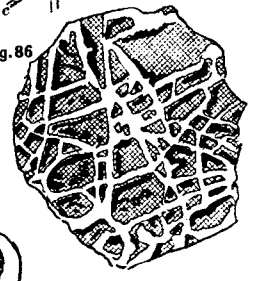

Fig.86

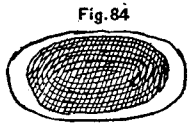

Fig.84

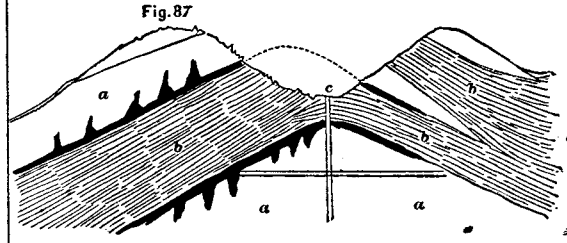

Fig.87

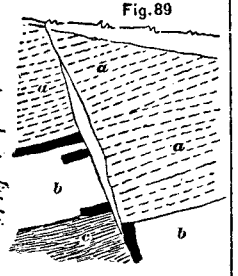

Fig.89

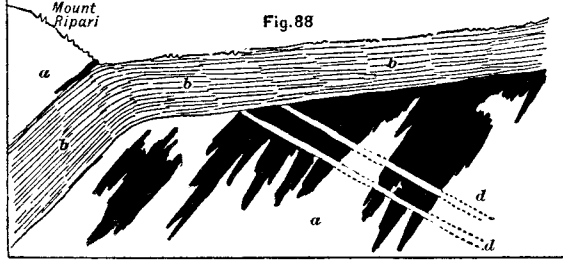

Fig.88

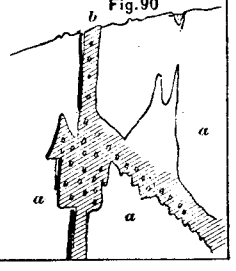

Fig.90

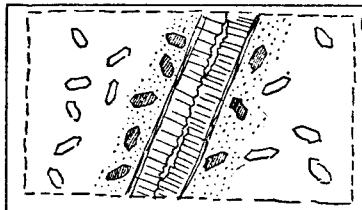

Fig.91

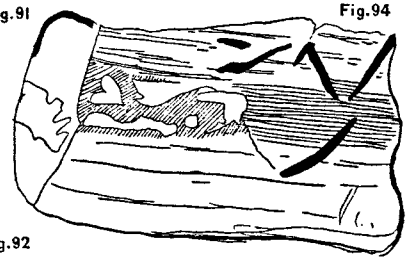

Fig.94

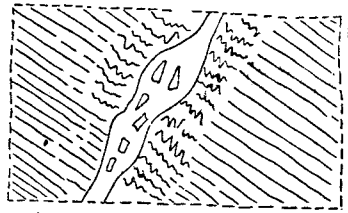

Fig.92

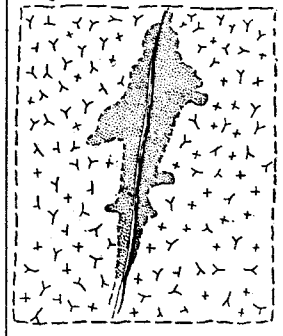

Fig.93

Fig.95

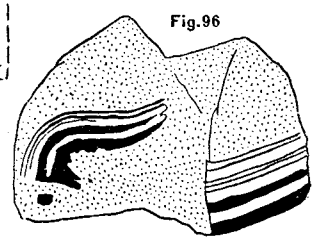

Fig.96

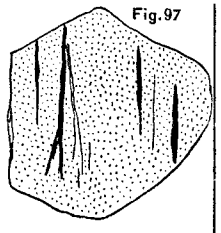

Fig.97

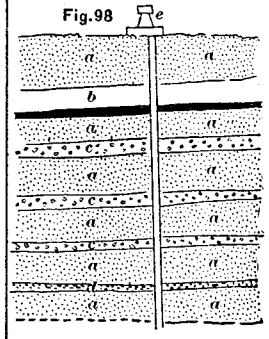

Fig.98

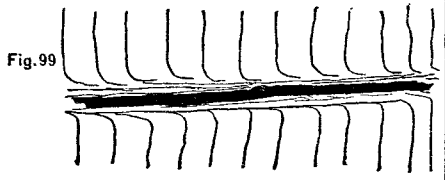

Fig.99

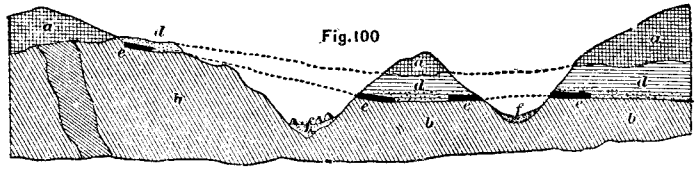

Fig.100

We distinguish the replacement of some constituents of a compound rock, for which the term "impregnation" is more appropriate, from the replacement of the whole homogeneous mass by metasomasis. But since every rock undoubtedly contains small primitive cavities, it is difficult, and sometimes impossible, to decide whether a new, xenogenous substance has not been deposited in such pores; and a case of this kind would fall under our notion of impregnation. The new substance may indeed have found entrance through the pores, if the mineral solutions were under sufficient pressure to overcome the friction of their walls, at least in the line of least resistance; and these solutions, thus introduced, may attack and replace one or another element of the rock. The entrance of such solutions will be greatly facilitated by the fissuring of the rock, whether by internal or external forces. We find in connection with ore-veins, and also with the thinnest mere seams, an impregnation of the country-rock, which Cotta has called subordinate or dependent (*unselbständige*) impregnation.

The particles of certain substances possess a peculiar mutual attraction. In the sandstone of Fontainebleau occur aggregates of calcite crystals, which have come together in spite of the separating medium of sandstone; and in a similar way, as we have seen, another substance of strong crystallizing power, namely, galenite, forms, in the pipe-ores and script-ores of Raibl, crystalline masses, in spite of the intervening diaphragm of a foreign medium.

In like manner are formed the so-called concretions, the calcareous and marly masses (*löss-kindlein*) in the loess, and the *marleker* of the ancient Scandinavian beaches. For the formation of the former, occasion was given by decaying plant-roots; for that of the latter, by various animal remains, mussels, fishes, &c. In Norway, they have preserved a complete fauna of the Glacial and Post-Glacial epochs.

Similarly, we find in some spherosiderite concretions of the Saarbrücken coal-basin the remains of fishes. A discernible nucleus is not always found in such concretions; sometimes no cause for this peculiar formation can be discovered. The concretions occurring in stratified rocks are usually lenticular, comprising portions of several similar strata. Even spherical forms, resembling pisolites, occur.

If we imagine, for instance, spherosiderite concretions formed closely side by side in one stratum, we shall have a regular bed of clay-ironstone. Leaving out of view the agency of fissures, or contacts with intruded rocks, impregnations following certain strata may be formed, constituting a second kind of ore-beds. A third kind may result from the more or less complete replacement of the original rock, especially when the latter is a soluble precipitate, like gypsum or limestone. In thick limestone formations the ore-beds occur at the contact with insoluble rocks, as at Rodna.

In all these cases the deposits have the form of a bed, but the ores rarely cover the whole contact-surface, occupying, on the contrary, only certain zones of it. In other words, in these as in other deposits ore-shoots occur.

Much more complicated relations result when the mineral solutions ascend along structural fissures and rock-contacts; and in order to a comprehensive description of this suite of phenomena, it will be well to consider first the simpler conditions obtaining in soluble rocks, and afterwards the more complex occurrence of such deposits in crystalline and eruptive rocks. We will, therefore, review the metamorphous deposits as they occur in (*a*) distinctly-stratified rocks; (*b*) soluble precipitates; and (*c*) crystalline schists and eruptive rocks.

(*a.*) *Metamorphous Ore-deposits in Distinctly-stratified Rocks.*

We find in unquestionable sediments not only metallic oxides and salts, but also sulphides, in the form of ore-beds, which, by reason of this stratigraphical relation, have been held to be of contemporaneous origin—that is, idiogenous. As a consequence, it has been necessary to assume that they were precipitated in a sea-basin, in which, before and after their precipitation, only barren sediments were deposited. These metals must, therefore, have been dissolved in the water of the basin, and that in very large quantity, as indicated by the frequently great thickness of the ore-beds. But for such an assumption we have no present analogy.

The Deposition of Ores from Sea-water.—In this particular, however, we have to do rather with suggestions than with demonstrations of fact. So far as sea-water is concerned, traces of metals have been found in the water itself, in the ashes of marine plants, and in the solid constituents of marine animals—for instance, corals—by Malagutti, Bibra, and Forchhammer. Traces of silver, iron, and manganese were detected in the water, and lead, zinc, cobalt, and nickel in the marine organisms; and, since there are in sea-water small amounts of hydrogen sulphide, Bischof considers the deposition of metallic sulphides from the sea to have been possible. He observes that the occurrence of metallic sulphides in sedimentary rocks, such as that of copper and silver sulphides in *kupferschiefer*, or that of lead sulphide in *buntsandstein*, may be thus explained; and even indulges in the following teleological conclusion: "Since it cannot be doubted that the rivers flowing into the ocean bring with them metallic salts, though in very dilute solution, it seems a wise arrangement that in the hydrogen sulphide of sea-water a precipitant is presented to throw down the smallest minima, and thus to prevent the gradual accumulation of substances *so injurious to animal life.*"

Of the various metals dissolved in sea-water, iron is least injurious to animal life. Indeed, animal life assists, in the so-called lake-ores, the segregation of this metal. Moreover, the precipitation of ferrous and ferric oxides from concentrated solutions is probable, so that a precipitation of iron-ores directly from sea-water seems to be established as a possible origin for some iron-ore beds.

But the conveyance of metallic salts by rivers to the ocean and the formation of hydrogen sulphide in sea-water are unquestionably continuous, and the precipitation of metallic sulphides must, therefore, have taken place uniformly in all sediments and precipitates of the ocean; whereas we find the ore-beds in fact only in certain strata. If these are to be thus explained, we must assume that the ocean was at certain periods much more strongly impregnated with metallic salts

—a scarcely tenable hypothesis as applied to the mighty deep—or we must suppose with Carnall, as H. Hoefer has recently done, a subsequent redeposition of the primitive metallic salts contained in minute quantities in the sea-deposits—in other words, their solution and reprecipitation at certain horizons. Hoefer cites the lead and zinc deposits of Upper Silesia and other districts, which occur in marine Triassic limestones. He assumes the maintenance of uniform horizons by these deposits to be demonstrated, but points out that some of these horizons were already ore-bearing when first formed.

In short, a number of investigators have adopted the hypothesis of an original ore-deposition from the ocean without giving any other reason than the observed relations of stratification. Yet, in a considerable experience with ore-deposits in marine limestones, genuine ore-beds are scarcely ever found among them, but always only ores of subsequent introduction; so that we are warranted in believing that such ore-beds proper do not exist.

As to the primitive ore contained in marine sediments and precipitates, innumerable chemical analyses, especially of limestone, have failed to show the metallic traces which, according to the above hypothesis, should be present.

Ore-deposition in Fresh Water.—The demonstration of direct ore-deposition in fresh-water strata encounters the same difficulties, though it may be supported by the same chemical speculations. Here the hypothesis is favoured by the analogy of the lakes of regions without drainage to the sea, in which the salts brought in by rivers are necessarily concentrated by evaporation. But, since organic life is restricted in these salt lakes to a few animal species, the analogy can have but a limited application. Moreover, it would be necessary to suppose cataclysmic changes, like the interposition of a period of no drainage in the midst of an epoch of fresh-water sedimentation.

Without the assumption of such cataclysms, we cannot believe that the Mannsfeld *kupferschiefer*, in which the organic (fish) remains can be traced continuously from foot- to hanging-wall, could be explained in this way. It deserves mention that some of the earlier geologists, like Freiesleben, accepted the sometimes contorted attitudes of the *palæoniscus* in the *kupferschiefer* as a proof of contemporaneous ore-depositions, and alleged that these fishes had been thrown into violent contortions by the copper solution, in which condition they died, and were buried in the sediment. The *naïveté* of this diagnosis, which, nevertheless, some modern writers have not hesitated to repeat, is evident. Contorted fish-remains occur in other formations outside of the *kupferschiefer*, and clearly show the advanced stage of decomposition in which the bodies reached the sediments.

The Kupferschiefer of Mannsfeld.—The Mannsfeld *kupferschiefer*, as is well known, is a thin bed of bituminous slate, lying between the Permian sandstone below and the marine member of the same formation, the *zechstein*, above, and containing sulphides of copper, silver, lead, zinc, antimony, mercury, nickel, and cobalt. The copper amounts to 44lb. to 66lb., and the silver to 4oz. to 5oz. troy, per metric ton of 2,204lb. In polished sections, the ore can be seen in thin leaves lying between laminæ of slate, and often accompanied by gypsum. But the same ores occur in scattered bunches in the sandstone below, and small bodies of redruthite are found in the limestone above. This circumstance alone, that ore occurs also in the marine limestone, above the fresh-water *kupferschiefer*, is unfavourable to the contemporaneous origin of ore and rock.

Kupferschiefer in Thuringia and Bohemia.—The same bituminous slate occurs in the Thuringian forest on the south slope of the Hartz, and at other points a considerable distance away. It must therefore have been deposited in a large basin. But it is a question whether it anywhere carries ore and deserves the name of *kupferschiefer*.

In north-east Bohemia, the same Permian slate, with almost the same fossils, is widely distributed, but without the marine member which covers it in Germany. The Permian of Bohemia carries copper-ores in many places; and in one locality, namely, at Hermannseifen, these ores occur in the bituminous slate, which might properly here be called *kupferschiefer*.

Precisely the same difficulty exists at Mannsfeld, and in the Thuringian forest, as Cotta reports in part as follows: "These conditions have influenced the ore-bearing character of the strata traversed by them. This influence is shown in the increase or diminution of the proportions of ore, not only in the immediate neighbourhood, but sometimes also for a considerable distance, even as far as the next master-fault. It is shown also in the transfer of the metallic contents from one stratum to another."

This and other observations concerning the influence of the faults upon the ore-distribution bear decidedly against the contemporaneity of the ore-deposits, and in favour of a later introduction of ore through the fault-fissures.

But this conclusion becomes much clearer upon a consideration of the remaining occurrences. Thus, according to Cotta, the *kupferschiefer* at the edge of the Thuringian forest is not so rich in ore as on the southern border of the Hartz. More important than the copper-slate itself are the fault-fissures which traverse the whole group of strata, but only carry ore in certain zones in which they intersect certain strata—the *kupferschiefer* among them. "Strange to say," observes Cotta, "near Camsdorf it is almost exclusively where the *kupferschiefer* has suffered such disturbances that it is rich enough to repay mining." In speaking of Riegelsdorf he says, "The cobalt-ores have in some cases made their way from the veins into the country-rock."

Westphalia.—At Stadtberg, in Westphalia, there are even several copper-bearing strata, and these are cut by copper-bearing veins. At Bieber, veins traverse the whole group of strata into the underlying mica-slate, and "the irregularly distributed ore occurs, strange to say, chiefly interleaved in the mica-slate, and not, as in the Hartz and the Thuringian forest, in the horizon of the *kupferschiefer;* while, on the other hand, the impregnations from the veins have penetrated chiefly the bituminous marly slate."

In consideration of the expressions partly quoted verbatim above, it is difficult to see how there can be any doubt of the secondary nature of the ore-deposits in the *kupferschiefer* throughout. Yet Groddeck has reproved me for coming to this conclusion. He says himself expressly

(evidently having in mind the typical Mannsfeld occurrence), "The ores were laid down contemporaneously with the slime deposit, the bituminous marly slate as the ore-matrix." . . . "It is entirely impossible that the ores could have entered the bed somehow from the fissures, at a later period, after the covering of the marly slate with more recent rocks. If we assume that the ore-solutions were introduced through the fissure faulting the bed, it remains inconceivable why the filling of metallic sulphides, through a field of many square miles, should be uniformly and exclusively confined to the stratum of marly slate, about 19·5in. thick, and should not also occur more or less near the fissures in the strata above and below, there being in these no lack of carbonates and bituminous constituents, available as precipitants of the solutions—the *stinkschiefer*, for instance, lying not far above the *kupferschiefer*, being rich in such substances."

Groddeck here overlooked the principle, elsewhere urged by him, that a single link in a whole chain of phenomena should not be exclusively considered. He contemplated only the special development at Mannsfeld; assumed, moreover, similar developments for many square miles, which show in fact many variations, and did not take into account the circumstance that when the *kupferschiefer* is not cut by fault-fissures it is also not valuable for mining. Finally, he was unacquainted with the theoretically important occurrence of the *kupferschiefer* in Bohemia. The contemporaneous origin of the ore and rock at Mannsfeld was with him, so to speak, a dogma, as may be perceived in some of his expressions: "The local ore-bearing character of the foot- and hanging-walls of the *kupferschiefer*-bed is no proof to the contrary, for it is always confined to the immediate neighbourhood of the bed. Into the sea, rich in fishes and plants, from which the marly slate was deposited, flowed abundant metallic solutions, which killed the organisms and were themselves reduced by the products of decay."

The first of these propositions becomes logical if it is simply reversed in sense; and the bold hypothesis of the second indicates a doubt which the author is seeking in this way to set at rest. His statement—"It is not to be doubted that metallic sulphides may be formed at the earth's surface, under ordinary pressure and temperature, beneath a water-covering which excludes the air,"—is quite correct; but when he adds, "and there is therefore nothing to prevent the belief that sulphuretted ores could be precipitated at the same time with the deposition of sedimentary rocks," it is necessary to add, "*provided* the metallic salts were present in the sea-basin."

This is, indeed, the centre of gravity of the whole question; and, as shown, the proposition presents an improbability.

Various other peculiarities of individual ore-occurrences are cited in favour of the theory of contemporaneous origin; but all of them, when impartially weighed, are equally consistent with a different genetic explanation, and fail to be as significant as the Mannsfeld type for the theory in question.

The Copper-sandstones of Bohemia.—In Bohemia and on the west slope of the Urals, the copper-ores of the Permian strata occupy by no means a continuous horizon, but occur as impregnations in different beds, beside, above, or below one another. There are here, as in the German *kupferchiefer* mines, fault-fissures which may have served as ore-conduits; and in these regions the notions of a primary sedimentary origin of the ores has not been so often suggested. At some places in Bohemia, as, for instance, at Starkenbach, melaphyres appear above the ore-beds.

In almost all these, as in many of the German deposits, the copper-sulphides, especially redruthite, occur in the neighbourhood of plant-remains; and oxidized copper-ores predominate, as a rule, in the ore-beds in sandstone.

Not only Permian but also Triassic and still more recent sandstones exhibit analogous deposits, containing lead, silver, and antimony, as well as copper. At Boleo, in Lower California, such an ore-deposit is known in Tertiary strata. The range of illustrations, therefore, is an extensive one; but only a few will be mentioned.

St. Avold.—Concerning the copper-ores in the Triassic sandstone of St. Avold and Wallerfangen, Groddeck gives a brief description, based on an article by C. Simon. The sporadic ores are most abundant in the vicinity of fault-fissures; but only single strata are rich, while other porous layers near by are barren of ore. The ores extend in zones, independent of the course of the fissures, which they often even cross at right-angles. These two features are said to prove the contemporaneous origin of the ore and rock, "since the enrichment of a zone where it is cut by the fissures can be simply explained by the leaching-out of ores in higher strata, and their redeposition in or near the fissure." But this explanation is not satisfactory. Figs. 80 and 81 illustrate the situation.

At Bleiberg, in St. Avold, concretions of galena, of pea-size, occur in the sandstone; and below the same layer considerable masses of solid galena are encountered.

The Lead-deposit of Mechernich, near Commern.—This deposit has a special interest in this connection, since it consists of sandstone of considerable thickness, somewhat porous, and impregnated with small concretions of galena (*knoten*), which have often been considered as contemporaneous in deposition with the rock. The district, situated on the north edge of the Eifel Mountains, embraces a zone about four miles and a quarter long, through Call, Keldenick, Mechernich, and Strempt. Already in the Roman period, at the Tanz Mountain, near Keldernick, mining was done upon galena veins in the Devonian limestone, which is overlain by the sandstone and conglomerate of the variegated sandstone formation. The conglomerate covering the sandstone has the name of *wackendeckel*, and sometimes carries ore, the cement between its pebbles being traversed by galena and oxidized products, especially cerussite, which were formerly mined.

It is at present the sandstone, impregnated with galena concretions (*noten*) to the extent of 0·5 to 3 per cent. of lead, and 0·03oz. to 0·18oz. troy silver, per metric ton of 2,204lb., which is the principal basis of an extensive mining industry.

The thickness of this *knotensandstein*, the number of these intercalated conglomerate layers, and the richness in ore of each stratum vary greatly, as do also the number, direction, and manner of throw of the fault-fissures by which it is traversed. Fig. 82, representing the stratigraphy southwest of the boundary of the mining grant at Meinerzhagen, shows the irregularity of the displace-

ments. Within the grant, the several *knoten*-layers are united into a single bed, about 72ft. thick, separated by a conglomerate layer from the Devonian rocks below, and overlain by another conglomerate, the so-called *wackendeckel*, above which is the barren red sandstone. In general terms, there lies here upon an impermeable floor a previous group composed of sandstones and conglomerates, overlain by argillaceous red sandstone and loam.

The *knoten*, never larger than peas, exhibit, when prepared in thin sections and mounted in Canada balsam, crystalline aggregates of galena, in which the crystal-faces are turned outwards, away from the centre; that is, they are by no means composed of spherical masses, as they seem to the naked eye to be, when examined as they come from the crumbly rock. Their distribution in the sandstone generally follows the bedding; but in the neighbourhood of the cross-faults an accumulation of *knoten* in zones parallel to these steep fissures could be observed. Moreover, occasionally in the fissures themselves threads of galena and pyrite was found; and hence, no doubt, the ore-deposition here was secondary, and proceeded from the fissures. To gain a clear view of this question, it is necessary to include the ore-occurrence in the conglomerates, where, as already observed, it impregnates the material cementing the pebbles, and also the nearest ore-occurrence in the Devonian limestone, where it appears in fissure-veins.

In my opinion, the loose, pervious sandstone, enclosed between less permeable strata, and cut by many fault-fissures, was impregnated by ascending springs, which employed it as a path in their circulation; but it cannot be determined what constituted the centres around which the galena concretions are formed. May it have been minute particles of feldspar, such as are occasionally visible; or was it organic substances, which have now entirely disappeared?

Freihung.—Perhaps additional hints may be furnished by the mines of Freihung, in the Bavarian Upper Palatinate, which Cotta considers analogous to those of Mechernich. Here galena and cerussite impregnate the *keuper* sandstone, the steep dip of which they share. At the Nuremberg Exposition of 1882, maps, ore- and rock-specimens from the mines of the Bavarian Lead-mining Company were exhibited. Fig. 83 is a section through the Vesuvius Mine. There were numerous specimens of tree-stems changed to galena; and on my coming subsequently into possession of such a specimen, a polished section was prepared from it. The pieces of these stems exhibited are about 8in. long, and elliptical in sections—say, 2in. to 3in. by 4in. to 6in. The fibre and the annual rings could be recognised on the surfaces of fracture, but were extremely plain in the polished section. Indeed, they were indicated by the cleavage of the specimens. Thin slivers, in my possession, 0·08in. to 0·16in. in diameter, and several inches long, represent the fibres of the original wood. The former bark is replaced by a zone of first pyrite, and then quartz grains cemented with pyrite. Fig. 84 is a diagram of the section of such a stem altered to galena.

Certainly we have here another instance showing that the organic substance attracted metallic solutions, and reduced them to sulphides, and this under conditions similar to those of Mechernich. The latter occurrence may, therefore, be most simply explained by the hypothesis of an organic substance, distributed through the rock, which reduced the circulating mineral solutions and occasioned the formation of the concretions (*knoten*).

Silver Reef.—Accustomed as we are to find silver associated with lead-ores, we are surprised by the occurence, in the Silver Reef district of Utah, in probably Triassic sandstones, of silver accompanied by copper. So far as can be gathered from the various descriptions at hand, there occur here two beds (the outcrops of which are called "reefs") which carry silver, either exclusively or with a little copper—the former usually as a chloride, but sometimes native; and the latter in the ordinary oxidized ores. It may be reasonably inferred that the deposit has been thus far exposed in its upper, chloridized, and oxidized zones; and that in depth it would be found to contain sulphide-ores.

The beds consist of red and grey argillaceous sandstones and arenaceous clay-slates, between the laminæ and in the cross-joints of which the ores occur, being the more concentrated the more highly fissured the condition of the rock. Although traces of silver are found throughout the bed, the pay-ore is confined to separate chimneys or channels, which descend on the true dip, or pitch obliquely to it. The richest bodies are said to be most frequently found above a certain thin, very clayey sandstone stratum. Very often, but not always, the silver-ore is accompanied by carbonized vegetation, such as trunks and stems of trees, and reed-like plant-remains, which are covered and impregnated with horn-silver. The copper- and silver-ores, while occurring to a certain degree in association, seem to exclude one another, and are seldom found in actual mixture.

The same sandstone which here carries ore is said to be represented in the plateau cut by the Colorado River; but there the strata are horizontal and undisturbed, whereas in the ore-district they dip rather steeply, are much disturbed, and are in many places covered with eruptive rocks, including basalt. This neighbourhood to eruptives renders it probable that here, as in so many other places in Western America, the ores have been introduced by the mineral springs which usually follow eruptive activity. Rothwell, Couch, and Rolker are of this opinion, whereas Newberry is inclined to suppose a contemporaneous origin of ores and rock. The principal arguments for his view are, the alleged great area of silver-bearing Triassic strata in that region, and the circumstance that the richest bedded and lenticular ore-bodies are inclosed in almost impermeable slate-clays, which would not have permitted a subsequent entrance of the mineral solutions. Neither of these statements disproves the secondary origin of the ores. They could have been deposited in any given way on a large scale, as well as a small one, and that the almost impermeable slate-clays did not prevent the entrance of solutions is proved by the subsequent alteration of the original filling to chlorides and oxides.

Moreover, the deposits are not regular strata, but chimneys and channels in parts of strata, and this character, which they possess in common with so many other deposits, should be decisive in favour of their secondary origin—a conclusion which, in my opinion, is always reached when observations are not confined to single localities, but extended over whole series of analogous phenomena.

Copper Deposits of New Mexico and Arizona.—Traces of similar ore-distribution in sandstones seem to be not infrequent in the America West. Thus F. M. F. Cazin says of the copper-ores of the probably Triassic sandstones of the Nacimiento Mountains in North-west New Mexico, which J. S. Newberry had described in 1860: "The ore occurs nearly exclusively as the petrifaction of the leaves, stems, limbs, and trunks of palms. Frequently the ore is coated with a film of jet or coal. It is always easily separated from the rock. The ore is predominantly erubesite, copper-glance, and melaconite, and it appears to be distributed all over the massive stratum, but is more densely collected on seams and cleavages, in some instances forming a single layer of petrified parts of palm-wood."

This occurrence, which is analagous to those in Bohemia, and in the Province of Perm, was declared to possess great economic importance. Its later developments are not known to me.

W. P. Blake has described an analogous occurrence in the sandstones and conglomerates overlying the granites in Copper Basin, Yavapai County, Arizona, where the copper-ores are found unconnected with any organic subtances. In the underlying granite, however, there are fissures filled with copper-ores. He thinks it probable that copper sulphides circulating in highly permeable sandstone were precipitated as carbonate by carbonate of soda, while the resulting sulphate of soda escaped in solution, to be concentrated by evaporation, forming deposits of thenardite, which is common in Arizona.

Lower California.—At Boleo, opposite Guaymas, on the Peninsula of Lower California, E. Fuchs has described a remarkable deposit of copper-ores in Tertiary sandstones, conglomerates, and tufas, which must be mentioned under this head. The east slope of the (mostly eruptive) mountain range extending through the peninsula is a plateau, gently descending towards the Gulf of California, and cut by precipitous cañons. It is formed of strata containing characteristic Miocene fossils. Tufas decidedly predominate, and the series contains three or four copper-bearing beds, covering a large area, and outcropping at many places in the cañons. These lie immediately upon conglomerates of pebbles of eruptive rock (different and characteristic for each horizon) and are overlain by clayey tufas. The whole is traversed by several fissures, of which the largest and most important is a fault-fissure, occurring at the western border of the district and striking about parallel with the sea-shore.

In the ore-beds above the ground-water level, disseminated oxidized ores prevail, such as black oxide of copper, and the protoxide, with atacamite ($CuCl+3\ CuO+3\ H_2O$), azurite, malachite, and chrysocolla, with crednerite ($2\ Mn_2O_3$, $3\ CuO$). In the second ore-bed (counting downwards) there are peculiar globular concretions, like oölites, of copper oxide and carbonate, sometimes several inches in diameter, which are locally called *boleos*, whence the name of the district. Though greatly interested in this type of ore, no specimens have ever been in my possession enabling me to form from the hasty description of Fuchs a clear conception as to its genesis.

The third bed lies in part below the ground-water level, and contains, in addition to the foregoing minerals, the copper-sulphides chalcosine (Cu_2S) and covelline (CuS).

The ore-beds are composed of tufa (the slime, according to Fuchs, of volcanic eruptions), in which ores in disseminated spots and veinlets, as well as globular concretions, are irregularly distributed, with a visible tendency to concentrate towards the bottom of the bed, where they form a compact ore-layer, 6in. to 10in. thick.

With regard to genetic questions, we must bear in mind that the fossils found in these strata indicate an open though not very deep sea: it is, therefore, impossible to assume that iron-, manganese-, and copper-ores were dissolved in it, and were precipitated from it at the same time with the rock. A periodical metallic precipitation, three or four times repeated, in an open marine basin, is out of the question; and we are forced in this case, even more strongly than elsewhere, to assume a secondary origin for the ores. The data necessary for its explanation is still wanting, but can undoubtedly be secured by the further advance of mining work. E. Fuchs contented himself with pointing out the after-effects of eruptive processes, and did not enter upon the genetic question. Certainly the conglomerates underlying the ore-bed must have played an important part, representing, very likely, the channels through which the mineral solutions ascended, to be reduced, probably by the presence of organic matter, in the tufas above.

(b.) Metasomatic Deposits in Soluble Rocks.

A metasomatic replacement of the original rock-material was clearly proved long ago for some instances—*e.g.*, calamine-deposits—while in other cases, where proof has not been obtained, analogies in the observed circumstances speak for such an origin. Parts of such deposits, it is true, may be fillings of spaces of dissolution, rendered unrecognisable, as such, by the absence of clearly-defined crustification in the ore-precipitates. We must accustom ourselves to the fact that for many deposits, not yet closely enough studied, it is impossible to determine positively the mode of genesis, and we must often choose provisionally, of the two modes just named, the one which appears to represent better the given data.

Calamine-deposits.—The calamine-deposits of Raibl in Carinthia, Wiesloch in Baden, Vieille Montagne with its vicinity, in Belgium and Germany, and other places, furnish, in the fossils of the limestone which have been transformed into calamine, the clearest proofs of a metasomatic replacement of the carbonate of lime by carbonates and silicates of zinc. Moreover, the structure and form of the ore-deposits is characteristic of this origin, these being mostly bodies of irregular outline, with portions projecting far into the country-rock. Often the progress of the replacement can be traced. Thus, at Raibl (Fig. 85), in places where the process has started from seams, the gradual advance from the seam into the rock may be observed; the outermost portions being relatively the most recent, and lying against a peculiarly uneven, rough surface of limestone.

Sometimes features of the original rock-structure are repeated in calamine, as, for instance, the cellular structure of the so-called *rauchwacke*, which consists of a skeleton of thin, smooth, lime partitions, from among which the limestone has been in part dissolved away, or left only in separate

decomposed splinters. This is evidently the result of a very complex metamorphosis, which Groddeck has observed also in the quicksilver deposit of Avala in Servia. The cell-walls, which represent the fillings of cracks in a shattered limestone, have been subsequently changed to calamine, and covered with botryoidal clusters of that mineral (Fig. 86).

Calamine is frequently formed by atmospheric agencies above the ground-water level, and is a frequent accompaniment of lead- and zinc-deposits in limestone.

Space does not permit the description here of the manifold deposits in Belgium, Rhenish Prussia, Westphalia, Upper Silesia, Sardinia, Algiers, &c., which are, moreover, not known to me by personal observation. The text-books of Cotta, Groddeck, and Phillips give some account of them, and refer to sources of more detailed information.

Laurium.—It is only in recent periods that the features of the extensive mining region of Laurium in Greece, worked two thousand years ago, have been described. Although various kinds of deposits are represented, most of them belong under the present head.

In the Camaresa district, a series of nearly horizontal, non-fossiliferous limestones and crystalline schists is cut by a number of eruptive dykes, and suddenly assumes on the north-east a steep dip, probably indicating a considerable dislocation. The whole group is traversed by a number of ore-veins which, in the schists, are often rich enough to pay for mining. But the main mass of the ores lies on the contact between limestone and schist, and extends into the former in separate bodies or shoots. At the so-called second and third contacts, the bodies have a prevailing funnel shape and a vertical position. Fig. 87, an illustration from Huot, shows the apexes of the funnels to point on one contact upward, and on the other downward—but, in either case, into the limestone, according as it overlies or underlies the schist. The first form may be explained by the pressure of the ascending solutions. The second, as shown in this figure, is perhaps somewhat ideally sketched; at least the sections of this third contact given by Cordella show ore-bodies following the contact-plane itself.

According to Fig. 88 (also from Huot) the ore-bodies are funnel-shaped in north to south section, but from east to west have a flat westward pitch, which is hard to explain unless it represents some kinds of cleavage parallel to the dislocation already mentioned. Below the second contact, which carries chiefly lead, there are (at the Jean Baptiste shaft, for instance, according to Cordella) great masses of calamine, the secondary origin of which from zinc-blende is doubtful, since it would involve the assumption that the ground-water zone had extended to this depth. As to the present subterranean water-level, the descriptions at hand contain only the statement that the region generally is very dry, and that the ancients, who mined to the depth of 394ft., had no water to hoist. With regard to the structure of the galena deposits, there were in the exhibit of the Cie Française des Mines de Laurium, at the Paris Exposition of 1867, masses of galena, blende, and pyrite showing distinct stratification, but it was not ascertained from which deposit they came.

Which of the various eruptive rocks of the district (eurite, porphyry, diabase, serpentine, trachyte) gave occasion for the ascending springs which brought up the ore cannot as yet be determined.

The minerals accompanying the products of decomposition in such deposits, particularly of calamine, are naturally often limonite and other ores of iron. In many countries these play an independent part, being often formed by the metasomasis of limestone, as proved by the irregular masses of the deposits and the contained fossils transformed into ore.

Alsace.—An instance is furnished by the so-called *bohneisenerze* of Alsace and adjacent regions which have been described and correctly explained by Daubrée.

At Liebfrauenberg, irregular lean beds of this character, composed principally of limonite, but scarcely workable with profit, lie on both sides of an anticlinal of Vosges sandstone, and are covered with alluvium. In one place, however, near Goersdorf, an undecomposed body of pyrite and mispickel occurs instead of limonite.

Cumberland.—In Cumberland, limonite deposits occur on the contacts of the Carboniferous mountain limestone, both with the overlying millstone grit and with the underlying Silurian schists. They are connected with fault-fissures, on both sides of which they appear, as shown in Fig. 89, taken from a paper by Mr. J. D. Kendall.

Carniola.—The Alps offer some remarkable examples of *bohneisenerze*. These occur, according to A. von Morlot, in the region of Woechin in Carniola (known for its iron-ores and bauxite) in the dolomite and limestone mountains only, and either in the form of beds under the dolomite detrius, or in clay, in the caverns of the dolomite. Fig. 90 is a section showing the latter form. In this case the flatter-lying cavern was partly filled with lime detritus and clay up to its connection with a higher vertical cavern, while the latter was filled with *bohnerze* enclosed in loam, and had been mined, according to Morlot, to the considerable depth of 820ft. Here and there a nucleus of pyrite is found in the iron-ore. The beds and mass-deposits of bauxite associated with limonite sometimes show also the "bean-structure."

(*c.*) *Deposits in Crystalline Schists and Eruptive Rocks.*

Without entering here upon a discussion of the subject of regional metamorphosis, it may be remarked that, as a rule, the older a rock is the more changes it will be found to have undergone; yet that these changes do not advance in all places uniformly. Many Cretaceous and Tertiary formations of the Alps pretent a high metamorphosed, and therefore ancient, appearance; while many Silurian formations—as, for instance, that which surrounds St. Petersburg—have been so little altered that the fossil shells which they contain still have the mother-of-pearl lustre. Some regions, in a word, have been more strongly attacked than others, through causes which we will not here pause to consider; and when we follow the stratified groups downward, we come upon the various crystalline schists, often traversed by eruptives, and showing no longer any trace of the clastic sediments, which have been wholly transformed to crystalline masses. We cannot hope to find petrified organisms in these masses; but the occurrence of disorganized organic material in the

form of anthracite and graphite proves that at the time the rocks were formed organic life must have been represented in the sediments.

Many indications available in the distinctly sedimentary rocks as guides in the determination of the relative age of their ore-deposits are here wanting. The bedding becomes more and more obscure, and is sometimes no longer distinguishable from the cleavage. Many of the ore-deposits in these rocks have also become in whole or part crystalline, adjusting themselves to the prevailing stratification or cleavage, so that most of them present a bed-like structure and form. Whoever believes in the possibility of a contemporaneous formation of the ores with the rocks will not trouble himself here with genetic speculations, but will see in these deposits simply "ore-beds," according to the old classifications.

Taberg, Sweden.—The circumstance that magnetite is a constituent of many eruptive rocks has inclined many geologists to regard masses of magnetite in the neighbourhood of such rocks as immediately belonging to them. This theory originated in connection with the Taberg deposit, in Smaland, Sweden, and was propagated by F. L. Haussman, W. Hissinger, and A. Daubrée; and Taberg has been regarded ever since as an example of the primitive existence of magnetite deposits, those of Kackanar, Visokaya Gora, and Blagodat being classed with it.

The question arises, where the line is to be drawn between an eruptive rock containing magnetite and a magnetite deposit. An eruptive rock, like that of Samakov, in the Pils Mountains in Bulgaria, from the weathered detritus of which magnetite is obtained by ore-dressing, is not properly an ore-deposit; but, on the other hand, that of Taberg, where the ore is not only finely disseminated in large amount, but also occurs in separate, solid veins, may fairly be so called. According to A. Sjögren, the rock consists of olivine, magnetite, and a little plagioclase, with mica and apatite as accessories. In other words, it is an already metamorphosed rock. Considering that at several places in Scandinavia magnetite occurs in the crystalline schists also, it seems unlikely that the magnetite of Taberg belongs to the primitive rock. This is confirmed by the observation of Th. Kjerulf, that all the ore-deposits of Norway follow the courses of eruptive rocks. Taberg will scarcely prove to be an exception, and may, therefore, be regarded as a secondary or xenogenous ore-deposit.

Before proceeding further, mention must be made of the action of the mineral solutions upon the country-rock of some veins, which might be also classed as impregnation. In this respect tin-deposits are most interesting, because they carry ore, not only in the space of discission, *i.e.*, the vein-fissure, but to a large extent in the neighbouring country-rock also. If the veins occur in granite, this is changed for a certain width into greisen—*i.e.*, it is robbed of its feldspar, which is even, in some cases, replaced by cassiterite and associated minerals. Thus are formed the beautiful pseudomorphs of cassiterite after feldspar, which adorn many mineral collections. (See Fig. 91.)

Figs. 91–93 are taken from C. Le Neve Foster. Fig. 91 represents the alteration of the granitic country-rock to greisen on both sides of a fissure, which is here filled with symmetrical quartz-crusts, to the central druse or comb. Often such fissures occur close together; and, since each has its own zone of greisen, the result is a *stockwerk*, constituting a metamorphosis of the granite, and formed by these fissures.

Cornwall.—In the slate or *killas* of the Cornish miners there is often a disturbance of the bedding in the neighbourhood of the fissure (Fig. 92), such as is observed in connection with fault-fissures elsewhere; but in this case the *capel*, or adjacent portion of the slate, is altered chemically also, being impregnated with quartz and traversed by streaks of ore. The fissure itself is filled with quartz, cassiterite, chlorite, pyrite, and fragments of the *capel*. When several fissures come together, the result is somewhat complicated, but can be reduced to the simple case just described.

Still more interesting is the tin-deposit of East Wheal Lovell, described by the same authority. At the side of a narrow quartz vein the ores occur in the granite, from which they are not separated by any definite boundary, so that the ore-body is an almost vertical shoot, confined to the neighbourhood of the fissure, yet lying in the country-rock. It is clear that a mineral water of high solvent power must have ascended under great pressure, in order to bring about such effects in a rock ordinarily regarded as insoluble. Fig. 93 shows the situation of one of these ore-shoots in granite, at the East Wheal Lovell Mine.

The ore-deposits in metamorphous and eruptive rocks occur especially in the great crystalline northern areas, in Scandinavia, Canada, and the north-eastern United States.

Scandinavia.—In Scandinavia, the science of ore-deposits, like that of petrography, has had a comparatively independent development. Although these countries have been often visited by foreign observers, few analogies with European deposits have been noted—chiefly, no doubt, because of the peculiar character of the occurrences examined, but also partly because of the differing standpoints and views of native observers. In recent times a difference of interpretation has developed itself between the Norwegian and the Swedish geologists; and the former, since Kjerulf, have approached more nearly the Continental view.

As already remarked, Kjerulf traces all the ore-deposits of Norway to the filling of spaces of discission, and particularly of a peculiar space, produced by the sliding of the rock along a bedding-plane, and locally called a *lineal*.

With respect to the ore-filling, he points out that the occurrence of the ore-deposits must always be studied on the large scale, and that this method shows the ore-deposits to occupy certain lines, characterized by the presence of eruptive rocks. The ores appear chiefly in the crystalline schists, but also in traces along the contact, and sometimes in the eruptive rocks themselves. In the first case, the different sulphides, mostly accompanied with quartz, lie parallel with the bedding or cleavage of the rock, and thus look like beds; but their secondary origin is indicated by the slickensides, the branching of the deposits, and other signs. Sometimes it is made evident by the course of the ore-masses cutting across the bedding or cleavage. In the Museum at Christiania

there are many large specimens of the ore, some of which, having been polished, show this structure plainly. Pictures of some of them have also been published by Kjerulf.

In this connection, the primitive ore-bearing character of the *fahlbänder* (so often cited by geologists as primary ore-beds, which enrich the veins by which they are crossed) is entirely denied. It has been proved that the ores of the Modum fahlbands are connected with the malakolite and the augite-rock which intrudes in "lineal" form between the steep strata of quartz-schists. Figs. 94 and 95 are intended to show the appearance of these deposits, formerly deemed to be beds. The former represents a specimen from the Kongens Mine at Roras, and the latter a part of the specimen illustrated by Kjerulf, from the Mug Mine at Trondhjem. In the former, the subsequent entrance of the ore is at once recognised. The latter appears as if the crystallization of the minerals had taken place after the ore-impregnation.

Of course, the political boundary does not divide the naure of the ore-deposits of the Scandinavian kingdoms. Those of Sweden are often the continuations of the Norwegian. The crystalline rocks are here peculiarly developed, and have also been peculiarly named by the Swedish petrographers. In the Swedish granulite, for instance, one would scarcely recognise its Continental namesake. These rocks are not in general so coarsely crystalline that their constituent minerals can be distinguished with the naked eye. The so-called eurites are still finely crystalline, and the *hälleflinta* is almost amorphous, consisting only of the ground-mass of the massive rocks. The beds and mass-deposits of the crystalline rocks are often, like many of the Norwegian deposits, associated with talcose and chloritic slates. Sometimes limestone is also present, as at Falun, Tunaberg, &c., where the ores lie on the limestone contacts. The ores of some of the deposits suffer in depth a remarkable change. Thus the mass of copper-pyrites at Falun has diminished in depth; but, on the other hand, gold-bearing quartz-veins appear in the midst of the pyritic body, and have yielded in recent years considerable amounts of gold.

Ammeberg.—There is here one of the most interesting deposits—namely, the zinc-blende mine of Ammeberg, belonging to the Vieille Montagne Company, which has personally been examined by me.

In a winding line, chiefly east to west, and about two miles in length, occur steeply-dipping beds of zinc-blende in granulite, or gneiss resembling granulite. At certain points they show very beautiful close folds. At first glance they seem to be genuine intercalated beds of the same age as the rock. The ores, however, do not continue along the whole line, but form separate lenses, up to 49ft. thick, which show a distinct stratification, consisting in layers of fine-grained to amorphous material resembling *hälleflinta*, alternating with the coarser granulite. Fig. 96 is a polished specimen, which exhibits clearly the secondary ore-invasion. The original bedding is here indicated by a series of light and dark dense *hälleflinta* layers; and these are broken through by masses of coarsely crystalline rock and of ore. The entrance of the ore into the coarsely crystalline layers seems to have been attended by an enlargement of their volume, which resulted in their breaking through the dense layers.

The same explanation is required for some parts of the bed, in which, between the plane surfaces of two fine-grained, barren strata, ore occurs in highly folded and contorted layers. This folding is due by no means to an exterior mechanical energy, but to interior chemical forces.

Some of the blende layers carry a considerable admixture of galena, as, for instance, the two ore-layers shown in Fig. 97, separated by a fine-grained, yellow to brown, barren stratum of eurite. The whole mass is traversed by fine fissures perpendicular to the bedding, which are filled with leaf-silver, looking like tinfoil. A replacement with ore of the original rock-constituents is here beyond question.

This Ammerberg deposit, then, although so distinctly bedded, is by no means of primitive origin; and still less can such an origin be supposed for the others, which occur as lenses of the greatest variety of filling, enclosed in the crystalline schists. If mica may be replaced with zinc-blende, magnetite, &c., such a change will, of course, be confined to certain portions of the rock, immediately within range of its cause; and these portions, as distinguished from the rest of the country-rock, are to be considered mineral deposits.

Some of the ore-deposits of the Alps have a certain similarity to those of Scandinavia, for instance, Prettau, in the Ahrn Valley, in Tyrol; Brennthal, near Mühlbach, in Salzburg; and Schneeberg, near Sterzing, in Tyrol.

Prettau in Tyrol.—There is here a very ancient copper-mining industry, which was overwhelmed in 1878 by a great disaster, and will not soon recover—viz., the settlement at the smelting-works was buried by an avalanche so deep in *débris* that it has been necessary to sink shafts nearly 65ft. deep and mine out the stock of manufactured copper and other objects of value.

The crystalline schists, which here strike east and west, and dip steeply south, contain impregnations of copper- and iron-pyrites, very short horizontally, but considerably prolonged on the dip. The deposit has been opened to a vertical depth of 1,640ft., representing 1,968ft. on the dip, so that the horizontal projection, or distance between the top and bottom, is only 1,088ft. Figs. 56 and 57 are a vertical section and plan. Figs. 54 and 55 are sketches from the roof and side of the Ottilie gallery, where the chlorite-slate and pyrites present highly complicated forms, somewhat like the structure observed in the Transylvania rock-salt. It may be explained, in my opinion, either by an interior increase of volume or by a distortion of the chlorite slate in the steep westward-pitching line indicated by the ore-deposit. It is extremely difficult to form a correct conception of this deposit.

It is remarkable that the pyrites-mine of Brennthal, near Mühlbach, shows an entirely similar structure and form of ore-bodies, and almost the same westward pitch upon the east-to-west plane of the stratification. It looks as if dynamic movements connected with the mountain had played a leading part in thus determining the same pitch for the ore-bodies of deposits on opposite sides of the Central Alps.

Where the ore-body begins to grow poor, and the pyrites appear disseminated in grains and crystals through the chlorite, the secondary character of the impregnation is clearly recognisable. The space for the massive ore-body was probably prepared by mechanical forces. That a metamorphosis was the cause is not likely, because the original minerals of the stratified group could scarcely have assumed such abnormal form and dimensions.

The older rocks occupy in America large areas; and there also many ore-deposits occur and are worked, which, although somewhat unlike those of Scandinavia, belong to a similar type.

Lake Superior.—The copper district of Lake Superior offers a number of very interesting circumstances, some of which, though developed by extensive mining, and often described at considerable length, have not yet been satisfactorily explained. It is remarkable that copper and silver occur here almost exclusively native; but it is very generally admitted that this is not the usual primitive form of copper. Sulphides seem to occur but seldom, and they receive, as a rule, no attention. Lac-la-Belle, an old working upon pyrite, chalcosite, and galena, once examined by me, was said to have carried some native copper in its upper levels. But Foster and Whitney do not mention it.

The native copper of this district occurs notoriously in both veins and beds, in a stratified group lying between the Huronian and the Cambrian, and traversed by numerous flows of eruptive rocks. We are here concerned with the beds. The ore in the Calumet and Hecla Mines is a conglomerate of porphyry pebbles; another, in the Copper Falls Mine, is a dark lava-flow, the so-called "ash-bed." The latter is impregnated with copper on both sides of the Owl Creek vein, which traverses it (Fig. 98); while in the Calumet and Hecla conglomerate, copper sometimes constitutes the cementing material.

In both masses the spaces now filled with copper were unquestionably once filled with other substances; and the present conditions are the result of whole series of complicated replacements.

R. Pumpelly, who originally believed in a contemporaneous origin of the copper and the enclosing rock, became subsequently convinced that the copper had replaced especially epidote and chlorite, and that certain phases of metasomatic processes were here represented. The eruptive rocks have usually been strongly attacked—for instance, the pebbles of the conglomerate, the rocks on Isle Royale, &c. Some portions, on the other hand—*e.g.*, the ash-bed—have been little attacked. The former instance (which the latter, it is true, contradicts) was used, long before Sandberger, as proof of a sort of lateral-secretion theory; and now and then, where the copper-bearing rock was overlain by an eruptive flow, the theory of descending solutions was also brought into play.

Some of the attempted explanations assume, in my opinion correctly, as the cause of the first ore-depositions the action of hot springs—in which connection it is only to be emphasized that these thermal effects occurred long after the intrusion of the eruptive flows between the sedimentary strata, so that the ores were brought, not by or in the eruptives themselves, but by the later springs, from great depths, and perhaps from considerable distances. This explanation, applicable to all the deposits, suits also the exceptional case cited by R. D. Irving—namely, the Nonesuch copper-bed in the sandstone of Porcupine Mountain, far from an eruptive outflow.

As to the condition in which the ores were first deposited, and the manner in which they became reduced and associated with zeolites, additional data must be sought for the formation of an opinion.

Sudbury, Canada.—Quite recently, A. B. von Foullon has published his observations in the Sudbury region, Canada, expressing certain theoretical conclusions of great interest, which, however, flatly contradicted my view. They concern the pyritic deposits which occur in Huronian rocks, but at the borders of eruptive outflows of diorite, &c., and were described by T. G. Bonney, and afterwards by R. Bell. The ores are associated with masses of diorite, intercalated conformably in the stratified rocks. The ore-bodies have the form of "stockworks," and consist of an irregular mixture of rock and metallic sulphides (?). In the ore, which contains gold, platinum, tin, lead, silver, zinc, and iron, occur also feldspar, quartz, and apatite. This account, taken from Bell's description, indicates a strong analogy with the Scandinavian deposits.

Foullon, who made in this field a series of highly valuable observations, supported by careful chemical analyses, expresses himself finally concerning the genesis of these deposits as follows: "The irregular mixture of pyrites and silicates, presenting copper-pyrites and magnetic pyrites enclosed in the rock in the most varied quantities and in all conceivable forms; and, furthermore, the circumstance that sometimes the ore occurs disseminated in the diorite, and sometimes the diorite is enclosed in the ore, now the rock, and again the pyrites, being the ground-mass, prove unmistakably their contemporaneous origin. At certain periods of the diorite eruption the magma was rich in accessory constituents, which rendered possible the formation of the metallic sulphides; and these were segregated during solidification."

R. Bell has expressed himself still more plainly: "The ores are not of humid, but of molten origin, as is proved by their occurrence in the diorite, with which they ascended. The masses of molten diorite must have remained long liquid, so that the metallic sulphides could separate, become concentrated at certain points, and continue with the fragments of diorite. Large quantities of the molten diorite, and the heavy metals, must have retired again."

These surprising statements assume a chemical impossibility—namely, the presence of metallic sulphides in the magma of the molten eruptive rock, after the fashion conceived by H. C. von Leonhard, on the strength of metallurgical analogies.

Shaft-furnaces, operated for a separation of the ingredients of the charge, produce slag, metallic sulphides (matte) and reguline metal. But the above hypothesis involves rather a common fusion of all, and a separation in cooling of slag (diorite) and matte (metallic sulphides). These authors should certainly not omit to explain further the principles upon which their explanation is based, taking into consideration at the same time the inner structure and other relations of the deposits in question, such as their conformity with the stratified rocks of the region, the occurrence of ore-channels quite similar to those encountered in deposits formed by aqueous circulation, &c.

These pyritic deposits contain almost all the heavy metals, including platinum and gold, and it is remarkable that the latter here occurs in quartz exactly as it does generally throughout the world.

The untenable character of the explanation above quoted must be evident, and this brief mention of them will be sufficient. Yet it appears that there are other inquirers into the genesis of ore-deposits who purpose to take a similar standpoint.

4. Hysteromorphous Deposits.

Under this title are included the deposits formed by the chemical and mechanical influences of the surface region, from the original deposits of which the conditions of origin have been considered above. These formations have been considered and named from various standpoints. Thus the name "deposits of débris" emphasizes the idea of a mechanical crushing or disintegration; the German term "*seife*," like the Spanish and American "placer," is based upon the manner in which such deposits are often mined for their metallic contents, and so on. The expression "secondary deposits" satisfies, it is true, the definition given above, but is rendered ambiguous by its frequent use in other meanings connected with the genesis of ores.

The influences of the present surface upon deposits found in the deep region are so characteristic as to permit us to draw conclusions concerning the processes of earlier periods, when the surface occupied a very different position. Unquestionably, effects similar to those of to-day were produced then also, and we must include in our consideration of the subject the hysteromorphism of former geological periods.

(a.) Chemical Effects.

The chemical effects proceeding from the present surface have been already discussed in many respects. They involve not only phenomena on the surface itself, but extend beneath it to the ground-water level, and even below that level, so far as the vadose circulation is traceable.

On the surface it is especially the oxidizing effect of the atmosphere, its contained carbonic acid, and the solvent and chloridizing action of atmospheric precipitation, simultaneously aided by the mechanical effects of wind and moving water, which bring about what Justus Roth has called "simple weathering," to distinguish it from more complicated forms of decomposition. In considering not merely rocks, but outcrops of complex ore-deposits, we encounter what Roth calls "complicated weathering."

Decomposition underground, through the action of the same atmospheric constituents of the surface-water, extends, as is well-known, to the ground-water level, where it may manifest itself in a striking way by reason of the frequent occurrence at that level of the alternation of dryness with moisture, which is a factor greatly promoting decomposition.

A similar condition is presented, as was pointed out in Part I., by the workings of mines, where the water-level has been artificially lowered, and a zone of depth previously untouched by the vadose circulation is brought within the domain of that agency. Deep and old metal-mines especially exhibit in a striking way the effects of the vadose circulation, and, in addition, a phenomenon but seldom found in places under the influence of the natural water-level—namely, the effect of the mine-waters upon various surface relations and products.

Limonite Deposit near Rio Tinto, Spain.—One of these rare instances is cited by J. A. Phillips in his group, "Deposits resulting from Chemical Action"—namely, in the vicinity of the great iron- and copper-pyrites deposits of Rio Tinto, in Spain, there occurs a deposit of hydrated ferric oxide, shown by the fossils it contains (which correspond with species still living in the region) to be of recent origin, and undoubtedly produced by the weathering and decomposition of the neighbouring pyritic deposit. It was deposited in a swamp-like basin with peaty matter, and subsequent erosion has left of it two remnants only, at Mesa de los Pinos and Cerro de las Vacas respectively. Evidently, in this case, the detritus of the pyritic deposit has not been mechanically swept away and collected elsewhere, but a chemical action has taken place, removing material in solution, exactly as in the formation of bog-iron-ores. The formation here is certainly earlier than the Roman period, for Roman tombstones have been found made of this recent iron-ore.

Mine-waters contain the solutions of all substances directly or indirectly dissolved by the vadose circulation, and some of these, encountering suitable precipitants, may be thrown down. Thus, ferrous oxide becomes by oxidation hydrated ferric oxide; many metallic sulphates are reduced by organic matter to sulphides; copper-salts may even be thus reduced to metal, &c. These new precipitates will mark the track of the mine-waters.

Finally, while the solutions formed by surface-waters, like those of the mine-waters, mostly find their way to the points where the water-level reaches the surface (drainage-points), yet, as a part of the ground-water penetrates to greater depths, such solutions may very likely produce, in the deep region itself, impregnations, which must, however, differ in character from those produced by the deep circulation proper.

The primitive deposit from which such solutions have come will show remaining in it principally substances not easily soluble, together with such as, like precious stones, resist all atmospheric influences. Meteoric waters carrying oxygen, some carbonic acid, and small quantities of chlorides, will first oxidize whatever is oxidizable, especially the metallic sulphides. On this subject S. H. Emmens has published a clear statement, with some practical deductions. He distinguishes in the order of liability to decomposition the following degrees: (1) Marcasite, (2) pyrite, (3) pyrrhotite, (4) chalcopyrite, (5) bornite, (6) folgerite, (7) millerite, (8) chalcosite, (9) galena, and (10) zinc-blende. The acid ferric sulphate formed from the first members of this series immediately attacks the latter members. The carbonic acid contained in the circulating waters has a high solvent power, and, among other things, dissolves the carbonate of lime as a bicarbonate, which reacts upon the basic sulphates, producing gypsum and free carbonic acid, and ultimately transforming lead-sulphate into carbonate (cerussite). Copper-oxide and, under some circumstances, native copper, may be formed from copper-sulphate, and so on.

For the chlorine of the chlorides, lead and silver have the strongest affinity, and these metals will consequently be often found in the upper zone as chlorides.

The decomposition above water-level of gold- and silver-bearing deposits facilitates the extraction of these metals. Metallic gold can be extracted by simple processes of mechanical concentration and amalgamation from oxidized material, while gold in undecomposed sulphides, &c., must be roasted, smelted, or chlorinated with more or less cost and difficulty. Silver likewise occurs, as a rule, in this upper decomposed zone in the form of easily amalgamated combinations (free-milling ores), while the refractory ores of deeper zones are much harder to treat.

It is doubtless for these reasons that mining enterprises often come into very critical conditions when they reach water-level, and many mines even cease to be profitable. An important part, no doubt, is played by other causes, such as the necessity of hoisting increased quantities of water, the cost of the required machinery, &c.

It is remarkable that in western North America the ground-water level lies deeper than is generally the case in Europe. The reason may be, that the present area of the interior basin of North America, which has no surface-drainage to the ocean, was formerly cut by deep valleys of erosion, which made a deeper escape of the ground-water possible. This suggestion is confirmed by the level valleys of Utah and Nevada, several miles wide and filled with very recent sediments, between comparatively narrow mountain ranges, which seem to be, so to speak, the tops only of the former ranges.

In Europe, the upper zones of the ore-deposits were worked out long ago, at a time when the science of chemistry was in its infancy. But we know from the remnants in these workings that chlorides, lead and silver carbonates, and various sulphates, such as anglesite, occurred in them, though they were not recognised. In Transylvania the decomposed products of the outcrop-zone were called *bräunen* ("browns"), with evident reference to the brown hydrated ferric oxide. The well-known maxim of the German miners concerning the "iron hat" is very ancient; and the same may be said of the Cornish proverb, "Gossan rides a high horse." Limonite is certainly a characteristic indication of the outcrop of an ore-deposit; and no doubt its reddish-brown colour has chiefly suggested the South American miners' names, *pacos* and *colorados*.

In a few instances the "iron hat" has been actually mined as an iron-ore. As a rule, it is the decomposed, porous, and honeycombed vein-material of the upper zone, and is coloured only with limonite. The part of the ore-deposit above water-level has a characteristic appearance. Quartz and other refractory gangue minerals are surrendered and impregnated by earthy limonite masses. As a rule the original texture of the deposit has become obscure: and sometimes fragments of the mineral crusts, broken off and crushed through changes of volume, are found chaotically thrown together. Occasionally, however, the original structure may still be traced in the decomposition products of the several crusts, unaltered nuclei of the ore being discoverable in them. Some substances (especially calamine formed from zinc-blende) display the stalactitic forms characteristic of the vadose region. Original druses as well as recently formed cavities are filled with new material; and in this way a secondary crustification may occur. There are some observations according to which gold has been precipitated chemically in hysteromorphous deposits. Oscar Lieber, F. A. Genth, and A. R. C. Selwyn expressed the opinion that detrital gold generally, or a portion of it, has been deposited from solutions. Laur, J. A. Phillips, Wilkinson, Newberry, Daintree, Skey, Egleston, &c., have accepted this view as more or less generally applicable. E. Cohen has undertaken to examine it critically, and is inclined by his own experience in South Africa "to adopt the conclusion reached by Devereux for the Black Hills of Dakota, and to assume that by far the largest part of the detrital gold has been liberated by the mechanical destruction of older deposits, and has been mechanically laid down; while, on the other hand, a precipitation from solutions undoubtedly takes place, but plays a very subordinate part only."

My own opinion on the subject is expressed in the above quotation. No doubt here and there, in the detrital deposits, traces of chemical activity are discoverable; but they are not sufficient to weaken the evident proofs of the mechanical origin of detrital gold.

(*b.*) *Mechanical Effects.*

The mechanical effects of moving air and water, of frost and ice, are grouped under the head of erosion, and are treated at length, so far as rocks in general are concerned, in the geological text-books. We are here concerned especially with effects of this kind produced upon those portions of ore-deposits which are exposed at the surface. We notice at once that mechanical, unlike chemical effects, are confined to the surface or a very small distance below it. In general, we must assume that the chemical changes took place first, but that the progress of erosion brings both to our view at the same time.

Verchoviky, or Surface-deposits in Sitû.—Not only water and ice (glaciers), but also wind, takes part in erosion. For instance, if an ore-deposit, by reason of its greater resistance, crops out above the level of the country, the wind will continually tend to blow away the finer and lighter portions of the detrites formed by chemical processes of weathering; so that, in the course of time, there must remain of the original outcrop only the heavier portions, so far as these are not carried away by water. In fact, my observations in the Urals is that the gold-diggings of the valley, undoubtedly formed by water, extended up the slopes to points where this could not have been their origin. The gold-bearing weathering detritus is there called *nagornyje rozsypy* and *verchoviky*.

A similar feature was observed by W. C. Kerr in the auriferous deposits of North Carolina; and I have seen it in the old gold-workings of Bergreichenstein and Nesvacil, in Bohemia, where flat mountain-ridges are covered with old pits and dumps. It is impossible to consider them as diluvial terraces, for the alluvium passes over, so to say, into the solid gneissic rock, which is traversed by many quartz veins. The gold occurs concentrated in the deepest portion of the weather-detritus—that is to say, on the contact with the bed-rock—and has penetrated all the open, loosely-filled fissures in the latter.

Cotta speaks also of deposits of *débris*—placers—which occur on high plateaus and mountain slopes, and consist of products of weathering which are not rounded pebbles or sand and slime accumulated by water-currents. A. G. Lock speaks of surface-deposits being "a result of the disintegration of the rocks *in sitû*," and says: "The gold it contains is quite angular, hackly, or crystalline, and is derived from auriferous quartz reefs or leaders existing in the immediate vicinity.

Similar conditions obtain very significantly in the Kackar district, to be hereinafter more fully described.

Theory of the Sinking of Heavier Constituents.—But the great agent in the transportation and redeposition of the metallic portions of original deposits has unquestionably been flowing water; and this is an equal factor in the removal of the rock-detritus of erosion, which it is constantly striving to carry to the ocean. River sediments are notoriously unstable. What is deposited this year is carried further down stream in the years next following, and so on, until it comes to comparative rest in the sea. The original deposits, furnishing the material thus transported over great distances and areas by water, are well called by the Russians *korennyje mestorozdenyje*, or root-like deposits—that is, as it were, the roots of the scattered hysteromorphous deposits.

The attempt has been made to explain the concentration, especially of heavy metals like gold and platinum, in certain paying layers of the detritus, by a sort of natural concentration process. The circumstance that the richest gold-deposits most frequently lie in the lowest stratum of the detritus, immediately on the bed-rock, yet that several such horizons occur one over the other, is difficult to explain in this way; for Cotta's assumed separate periods of formation are scarcely satisfactory, involving as they do either periodic transportation or periodic deposition, neither of which is probable.

In the Ural gold-placers a much more probable explanation is found, based on the principle that the specifically heavier elements of a loose mass are able, with the aid of water, to work their way down through the lighter portions. At the Przibram concentrating-works, it is found that if the pulp is left standing for a considerable period, the galena will accumulate at the bottom. In gold- and platinum-concentrating establishments, it may be often observed that these heavy metals find their way into the floor and woodwork of the mill, from out of which they are from time to time recovered by working up these materials. Why should this happen in artificial operations only, and not also under natural conditions, where the descent of the heavier portions is essentially aided by the percolation of atmospheric waters through the loose covering-material?

This view is supported by the features of all gold-placers, especially those of the detritus of weathering in place, where the agency of running water cannot be adduced, and the accumulations of gold at the contact of the loose and the solid material must be explained by its sinking through the former.

Stream Detritus.—The detrital deposits produced by running water are generally characterized by the predominance of permeable material, such as sand, gravel, &c. Under this covering mass lies the solid, impermeable "bed-rock" or "rim-rock" of the Americans, the *plotik* or *posva* of the Russians; and in all the goldfields of the world the richest pay-deposits are found, as a rule, at the border between the cover and the bed-rock. If the latter is decomposed, fissured, or otherwise loosened, the fine gold will sink into it, making it sometimes rich enough to be mined and concentrated; and this occurs without regard to the petrographic character of the rock. Thus, in the Ural, Palæozoic schists, limestone, and eruptive rocks indifferently are charged with gold. This circumstance indicates also the error of the assumption that these bed-rocks originally carried gold.

But layers of impermeable material sometimes occur in the cover, as, for instance, lava-beds in Australia and California, or, in general, solid conglomerates and clays. In such cases there is often a concentration of gold on the more solid layer, called in America the "false bottom," and in the Ural *loznyj plotik*—that is, a material erroneously taken for the bed-rock. There are often in the detrital cover two or more such gold-bearing layers, which are easily explained on the theory above suggested. The hypothesis of a natural concentration in running water is embarrassed by the fact that the material of gold-placers shows no arrangement according to size, but consists, as a rule, of elements of all sizes.

The movement of the elements of a loose mass has been already pointed out by W. C. Kerr, who admits the possibility, according to A. G. Lock, of the sinking of the heavier particles, though this is only in a passing remark, and without indication of its far-reaching importance. He says, "The superior weight of the precious atoms would cause them to sink through the moist surrounding matters, till a hard layer was met with. The occurrence of this process would constantly add to the deposits, the gold always gravitating to the bottom, quickly or slowly, according to circumstances."

It seems to me that this idea must have impressed itself upon other impartial observers also; and I can only wonder that it has not been more frequently expressed.

R. Helmhacker has recently communicated some observations on the Altai region of Siberia, such as the sinking of heavy metallic objects in the loose wash, which confirm the above views. Among other things, he identified grains of metallic lead formed in the gold-placers, as shot, scattered in hunting, which had sunk into the earth.

As is well known, auriferous detritus occurs not only in present but also in ancient river-beds, long since dry; and since, in the latter, the remains of diluvial animals, such as the mammoth, &c., have been found, a distinction has been made between alluvial and diluvial gold-deposits. But discoveries of yet older organic remains have shown that such gold-deposits were formed in still more ancient periods. The old river-beds of California cross the present streams, and the auriferous detritus of the former is covered with thick lava-beds—a feature which may be observed in Australia also. During the deposition of the gold, therefore, conditions very different from those of the present day must have obtained.

In another respect, also, the relation between ancient and modern river-beds is sometimes peculiar. The late channels have been rendered by erosion deeper than the older ones. But on the eastern slope of the Ural this is almost totally reversed. The diluvial gold-deposits characterized by the remains of the mammoth often lie below the water-level of the present streams, so that the latter must be diverted in order to mine the ancient beds. This condition apparently extends throughout the whole Siberian Plain, and may be taken as evidence that the erosive energy of its rivers has decreased since the Diluvial period, their fall having been reduced, either by the accumulation of the erosion-detritus or by changes in the relative altitude of the Ural Range.

The eastern slope of the Ural is characterized by numerous lakes and swamps along the tributary streams, and a number of these contain auriferous detritus, which has been mined for gold.

Marine Detritus.—In some regions, the auriferous detritus, after being repeatedly deposited and again swept away, to be redeposited further down the valleys, has at last reached the sea. The coast of Oregon, in western North America, and Vladivostock, in south-eastern Siberia, are examples. Here the ebb and flow of the tide operate very nearly on the principles of artificial ore-dressing; and one would think that a concentration of the heavier particles might be thus effected. But it does not appear that such effects have been recognised hitherto.

Kackar District, in the Ural.—At the beginning of this section, in the discussion of features of auriferous erosion detritus, some characteristics of the Ural placers were described. A few additional particulars concerning them may be of interest. The gold-bearing stratum occurs at no definite depth. As a rule, the whole of the barren or poor cover is stripped off and thrown aside before the auriferous layer thus laid bare is systematically attacked. Open cuts in the surface, of greater or less depth, are thus created, and are usually left to be filled up by the rivers. In the district of Kackar, already mentioned, in the Southern Ural, original gold-deposits ("root-deposits") of gold have been repeatedly found in the bottom of these cuts. They were well-defined quartz-veins, carrying in the upper zone free gold, but at greater depth sulphides and arsenides rich in gold. The original open cut extended for a considerable distance along the strike of the vein; but the bed-rock (which was at the same time the country-rock of the vein) was much decomposed, so that the difference between detritus and bed-rock was not strikingly evident; and the placer-working passed only by gradual stages into vein-mining.

Hysteromorphous gold-deposits may thus be said, in a general way, to occur in the following positions: 1. In the simple detritus of weathering, immediately upon the original deposit (root-deposit). 2. Mixed with the sand and gravel of present streams. 3. At certain points, in the river-bottom, into the crevices and fissures of which the gold has sunk. 4. Mixed with the impermeable material of older water-courses, through which the gold could not sink. 5. On the false bottoms or bed-rocks. 6. On the true bed-rock. 7. In the decomposed bed-rock itself.

In considering the chemical changes of the outcrops of deposits (including, of course, those which give rise to hysteromorphous derivatives) we have seen that sulphides suffer total decomposition, and that of their constituents only the unoxidizable metals, such as gold and platinum, remain unaffected. Silver-ores and native silver, being attacked by the chlorides of the vadose circulation, are consequently not found in hysteromorphous deposits. But gold occurring in nature is for the most part alloyed with silver. The gold from the veins of Budweis, in Bohemia, contains by weight about two parts of silver, and that of Transylvania contains by weight more than three of silver, to ten of gold. Whenever the gold of an original or root-deposit has been compared with that of its derived placer, the latter has been found to be of greater fineness—that is, to contain less silver. This phenomenon may be ascribed to the prolonged contact with water containing chlorides. The dull surface of placer-gold and its frequently spongy interior structure, as compared with the lustre and solidity of "quartz-gold," favour this explanation.

Platinum Placers.—Detrital deposits of platinum have been, until recently, particularly observed in the Ural only, from which the main supply of platinum was derived. Additional localities are now reported in the Altai district of Siberia, and in Canada and British Columbia. In the Tulameen district, it is said, the hydraulic method of mining has been introduced for platinum.

In the Ural, and particularly in its most productive district, that of Niznyj Tagil, the conditions closely resemble those of gold-deposits. The richest platiniferous layers are on the true bed-rock. Platinum and its associates, palladium, nevjanskite, and siserskite, being found to occur occasionally adhering to olivine and chromite, it was inferred that they were derived from the serpentine, which is itself a secondary product from olivine-rocks. More recently, platinum is said to have been found in an olivine-gabbro not yet metamorphosed; but whether the metal is a primary or an exotic constituent can as yet scarcely be declared with certainty.

Formerly no other occurrence of platinum than the native metal was known; but now a platinum-ore has been found in the Sudbury district, Canada, namely, sperrylite, a compound of platinum and arsenic. Since this is certainly xenogenous, the question as to the original sources of platinum deposits is advanced to a new phase by its discovery.

Tin Placers.—In connection with the occurrence of tin as cassiterite in detrital deposits, the specific gravity (6·97) of this mineral, nearly equalling that of iron, and the great resistance which it offers to natural agents of decomposition, doubtless play the principal part. Of the numerous and various associates of cassiterite in its original deposits, none, except quartz, are equally able to resist decomposition; and the consequence is that the detritus, both of weathering and of erosion, from the outcrops of such deposits, contains, besides the products of the decomposition of these other minerals, chiefly quartz and pieces of cassiterite. The latter, by reason of its high specific gravity, will tend to sink through the lighter detritus and be concentrated near the bed-rock.

The stanniferous detrital deposits of Bohemia and Saxony, as well as Cornwall, were long since exhausted; those of Australasia, the South Sea Islands, and South America are still worked. According to the special monograph of Dr. E. Reyer, the richest layers are, in fact, found at the bottom of the detritus, immediately on the bed-rock.

With regard to the geological age of the detrital tin-deposits, the rule stated for gold generally obtains—namely, they are of the most part diluvial, yet have sometimes been formed in earlier periods. Thus, at Platten, in Bohemia, a tin-placer, which has been worked under a bedded flow of basalt, and the detrital deposits of Anhaberg, in Saxony, which underlie the basalt of the Schebenberg, were doubtless formed in Tertiary times.

The original or root-deposits of tin have been hitherto quite generally considered as very old formations, connected with the eruptions of granite and felsite-porphyry.

Recently, however, tin has been found in the Mesozoic limestones of Campiglio Maritima; and it has been shown, moreover, that the root-deposits of tin in Mexico and Bolivia occur in trachytes and andesites, erupted during the Cretaceous or Eocene. Dr. A. W. Stelzner has recently published a notice of the latter occurrence, and promised a more elaborate description. He says: "The part played in geological history by the tin-ore of Bolivia contrasts sharply with that which has been observed in the Erzgebirge of Saxony and Bohemia, and in Brittany, Cornwall, East India, Australia, Tasmania, and the United States of America, and which has hitherto been willingly regarded as the exclusive method of tin occurrence. The Bolivian tin-ore does not constitute aureoles surrounding plutonic granite, and characterized by the contemporaneous presence of minerals containing borone and fluorine. On the contrary, it can only be considered as produced, simultaneously with precious silver-ores and sulphides of copper, iron, lead, and zinc, by precipitation from mineral springs, which were connected in point of time, and perhaps also as effects, with outflows of Cretaceous or Lower Tertiary volcanic rocks."

(c.) Hysteromorphous Deposits of the Older Geological Formations.

Twenty-five years ago, at a time when no deposits of this kind were known, in an article on the continuance of ore-deposits (especially of gold) in depth, my researches then showed me that they would be discovered. They have since been observed in different gold-districts. This refers to the characteristic secondary deposits in quartz conglomerates, indicated by their stratigraphical positions and their contained fossils to be of considerable geological age. Such occurrences are often called simply cement-beds, as are the conglomerates of cemented gravel in recent placers; and it is difficult in cases where, as in Australia, this term is frequent, to infer the age of the corresponding conglomerates. It is, however, in some cases unquestionable that these cements actually represent old formations—chiefly Palæozoic—and are therefore hysteromorphic products from still older primitive deposits.

Deadwood, Dakota.—One of the best described occurrences is that of Deadwood and Blacktail Gulches, in the Black Hills of Dakota. It is a conglomerate bed, passing upwards into sandstone, and belonging, according to the contained fossils, to the Potsdam sandstone (Cambrian). It is by no means a river-deposit; on the contrary, the fossils indicate a shallow marine basin. The series lies very flat upon crystalline schists; is at most 100ft. thick, and is covered by a layer of porphyry, which has most probably protected it from erosion. Fig. 100, a section given by Mr. Devereux, shows how the deposit is exposed and rendered accessible on the sides of Deadwood and Blacktail Gulches, which cut through into the underlying schists.

The conglomerates of pebbles of quartz, schist, and hæmatite which lie at the base of this Cambrian series carry partly coarse gold, under such circumstances that there can be no doubt of its secondary origin. It came probably from the Homestake vein near by. The auriferous detritus is about 6·6ft. thick, and the portions next to the underlying rock are the richest; so we have here the relation of the "true bed-rock." If my theory be correct, that the gold reached this position by sinking through the lighter detritus, it might be said that the gold was deposited not *with*, but *after*, the detritus, and consequently that the Cambrian fossils do not prove the Cambrian age of the gold-deposition. Such an objection might perhaps have weight in other cases of the kind, but in this case, the bed being covered by a porphyry overflow, and hence not at all exposed to later deposits, the objection has no force.

The Black Hills contain representatives of the three principal types of gold-occurrence—namely, gold-bearing veins, and ancient and recent detrital deposits. The paper of Mr. Devereux is also very interesting in other respects—for instance, with regard to the explanation of the different fineness of vein- and detrital-gold, and with regard to the traces of the chemical action in the detrital deposits.

Australasia.—The data from Australasia concerning this class of deposits are less conclusive. In 1876 Wilkinson observed in the Talhawang District of New South Wales that the Tertiary detrital deposits received their gold from carboniferous conglomerates. These conglomerates were associated with sandstones and slates, in which occurred a fossil plant peculiar to the Carboniferous period in New South Wales. The gold occurred in pretty coarse, rounded grains, and on one occasion a nugget was found weighing 5oz. Similar conditions are said to obtain in the Hawkesbury rocks, at the North Shore, Sydney, at Govett's Leap, and in the conglomerates of the coal-measures in the Southern district. Gold is also reported in the coal-measures at Peak Downs in Queensland, near Hobart Town in Tasmania, and in New Zealand.

The question, whether these deposits of gold were really made simultaneously with that of the detritus in the Carboniferous period, may be decided by the circumstance that the conglomerates are or are not covered by Carboniferous strata. In the latter case it is possible that the gold may have sunk into the gravel at a later period.

South Africa.—In South Africa, at Witwatersrand, in the Transvaal, ancient detrital deposits have yielded a considerable gold-production. According to E. Cohen, the Witwatersrand consists of sandstones (which resemble closely that of Table Mountain at the Cape of Good Hope) and dolomites of high age—undoubtedly Palæozoic. Conglomerates of the same age, intercalated among these strata, occur in the vicinity of Johannesburg in several nearly parallel outcrops, and are for certain distances tolerably rich in gold. They are composed mostly of quartz pebbles, sometimes with fragments not entirely rounded, which are united by a strong, ferruginous, arkose-like cement.

The quartz pebbles are sometimes porous and impregnated with hydrated ferric oxide, thus presenting the peculiar corroded appearance so characteristic of auriferous quartz. The gold occurs chiefly in the cement, immediately next to the pebbles. It is mostly coarse-grained, and sometimes even crystalline. The latter circumstance has raised the question whether the gold has not here been chemically precipitated, and hence, whether these are detritus-deposits at all. My standpoint in this discussion, as remarked at the end of the section on chemical effects in the upper region, is like that of E. Cohen. So far as can be judged from the treatises of A. R. Sawyer and Charles A. Alford, and from a specimen of the Witwatersrand conglomerate kindly sent to me by A. H. Halden, of Pietersburg, it is my opinion that the gold was mechanically brought into the conglomerates from still older auriferous quartz-veins occurring in the rocks which form the basis of this Palæozoic formation; and since the idea of a later entrance of the gold is excluded by the almost vertical position of the conglomerate beds near Johannesburg, which leads me to suppose the gold to have been deposited at the same time as the detritus. The greater part of the gold, at has been said, occurs in the cement. There are no vein-like deposits whatever in the conglomerate; and the only chemical changes which could be presumed are confined to the decomposition of pyrites and the segregation of its contained gold.

According to a foot-note in Phillips's "Treatise on Ore-deposits" gold is washed out of granular conglomerates of the Lower Carboniferous at Bessèges, Department du Gard, France.

Bohemia.—In the region of Trautenau in Bohemia, Gabersdorf, and Goldenöls, considerable traces of ancient placer-mining have been discovered, partly in the valley-bottom, partly on the slope, which consisted of old Permian and Carboniferous conglomerates. These remains looked exactly like other gold-workings in Bohemia, and their situation could only be explained by supposing that this was another case of auriferous Palæozoic detritus. The same may be said of another enigmatical gold-occurrence, at Stupna in Bohemia, where in 1593 a gold of unusual fineness (0·954) for Bohemia was produced, and must have come from a detrital deposit. The ancient miners penetrated through bedded flows of melaphyre. The waste-dumps are composed of pebbles from Permian conglomerates. It is therefore possible that these mines were operated upon auriferous Permian conglomerates.

MINE-MANAGERS' EXAMINATIONS.

During the last year six applicants came up for examination for a first-class mining manager's certificate, and two for a second-class certificate under the Mining Act, and four applicants for first-class certificates under the Coal-mines Act, also eight applicants for certificates as engine-drivers. Out of these, there were four passed their examination successfully for first-class certificates, and five for engine-driver's certificates, as shown in the following list:—

Mine-managers under "The Mining Act, 1891": F. W. Linck, R. Tierney, W. J. Standford.

Mine-manager under "The Coal-mines Act, 1891": N. Milligan.

Engine-drivers under both the Mining and Coal-mines Acts of 1891: T. McAuley, for water-power; M. Wynn, for water-power; M. Ross, for steam-power; S. Cook, for steam-power; C. H. Lawn, for steam-power.

"THE MINING ACT, 1891."

QUESTIONS USED IN EXAMINATION OF MINING MANAGERS FOR FIRST-CLASS CERTIFICATES.

FIRST DAY.—TIME: 9 A.M. to 12 NOON.

[Candidates must attempt to answer every question. All calculations to be shown in detail.]

SUBJECT A.—*The Laying-out and Construction of Shafts, Chambers, Main Drives or Levels, Uprises, and Stopes.*

1. Describe how you would commence to sink a vertical shaft where there was surface-water.
   (*a.*) What provision would you make to prevent the water following down the shaft as it was sunk?
   (*b.*) If the ground was loose sand, liable to run as soon as water was reached, what provision would you take to insure the stability of the shaft?
   (*c.*) How would you keep it plumb?
   (*d.*) In sinking an inclined shaft at, say, an angle of 60° from the horizontal, how would you carry the shaft down at the same angle, and keep it from twisting?
2. In sinking an inclined shaft where there was water to contend with, what provision would you have to bale the water and raise the excavated material?
   (*a.*) How would you open out from the bottom of the shaft?
   (*b.*) What is meant by a "sump," and why is it necessary?
3. In constructing a vertical uprise-shaft for, say, 120ft. in gravel drift where there were large boulders, how would you carry on the work to insure the safety of the workmen if the boulders had to be blasted and the ground were liable to run?
4. If a lode were dipping at an angle of 65° to the westward, and you had to construct an adit-level from the face of a range having an inclination of 1 in 5 to the eastward, what length of an adit would you have to construct so as to have 150ft. of backs on the lode? Also give the vertical depth.
5. How far apart would you have passes in stoping out a lode, say, 7ft. thick? and give the dimensions of the passes you would construct.

SUBJECT B.—*On the Timbering of Shafts, Adits, Main Drives or Levels, Passes, Stopes, and generally on the Systems of Timbering Mines, and also on filling up Old Workings.*

1. If you were constructing a shaft in ground liable to swell, what size of planking would you use? Give your experience in sinking shafts in ground of this description, and the precautions you adopted to insure the timber from breaking.
2. Show by sketch how you would fix guides and use cages in winding from an inclined shaft; and describe the advantages and disadvantages there are in working from inclined shafts.
3. Show by sketch how you would timber passes, giving their dimensions. Also show by sketch how you would timber a main level so as to keep all the remaining sets in position in the event of one cap breaking down.
4. What dimensions of timber would you use for a main level, if the ground was very heavy, to provide for a double road? and state how you would slab the ground if it were liable to swell. Give the size of the sets, inside measurement.
5. If you had to construct a tunnel or adit-level through blue reef which was hard when first exposed to the atmosphere, and after a short time got so soft that the props would sink into the floor, what provision would you adopt in timbering it?
6. Give the breaking-strain on a cap of rimu 14in. in diameter and 6ft. long in the clear inside the props. Also give the safe load on a prop of kauri 6ft. long and 12in. in diameter.
7. If you had to place two bearers 8ft. long across a shaft, to carry a column of pipes full of water, say of 80 tons weight, what size of bearers would you use, say of kauri, to give them 4 of a factor of safety.

FIRST DAY.—TIME: 2 P.M. TO 5 P.M.

SUBJECT C.—*On the Drainage of Mines, and Pumping Appliances.*

1. Describe the various systems of drainage, as applied to mines.
2. Describe in detail and mention all the parts of a pump capable of raising water to a height of 480ft.
3. What limits the height to which water can be forced?
4. From what depth will a pump draw water? and give your reasons.
5. How many tons of water would a pump lift in twenty-four hours, making sixteen strokes per minute; diameter of pump, 18in.; stroke, 8ft.; efficiency of pump, 70 per cent.?
6. What horse-power would be required in No. 5 question, the water to be raised 650ft.?
7. What thickness of cast-iron pipes would be required for top and bottom lengths: diameter of pipe, 18in.; height, 650ft.?
8. What would be the weight of pipes in Question No. 7?
9. Explain the use of the siphon, and its application underground.
10. Can electricity be applied in the drainage of mines? If so, how is the current generated, and how applied to pumping appliances?

SUBJECT F.—*Tapping Water in Mines, and the Mode of constructing Dams in Underground Workings to keep the Water back.*

1. Show by sketch how you would construct a concrete or brick dam in underground workings to keep back the water.
2. Show by calculation the pressure on the face of a dam 6ft. square if the water stood 150ft. above the centre of the face.
3. How would you approach a place where there was known to be a lodgment of water? and describe how you would tap it.
4. If in sinking a shaft in rock you found a stratum carrying water, how would you dam back the water to prevent it going down the shaft? Describe fully.
5. If you were driving through alluvial drift to tap water in old workings, state how you would secure the drive in approaching the place where the water was to be tapped.

SECOND DAY.—TIME: 9 A.M. TO 12 NOON.

SUBJECT D.—*On the Haulage in Shafts and on Underground Planes; also on the Strength of Haulage-ropes and -chains.*

1. What are the provisions in the Mining Act as to the inspection of machinery, ropes, and cages?
2. Describe a safety-catch, and how applied to a cage.
3. What appliances are used to prevent overwinding?
4. What are the regulations as to signalling in shafts or on planes?
5. How many different appliances are used for signalling?
6. What, in your opinion, is the safest and best appliance for signalling? and give your reasons.
7. What is the safe working-load on a $\frac{3}{4}$in. close-link chain?
8. What is the safe working-load on a $3\frac{1}{2}$in. steel-wire rope?
9. What horse-power would be required to raise 430 tons quartz 640ft. in twenty-four hours (neglecting friction; cages balanced)?
10. Give dimension of boiler or boilers suitable for engine to accomplish work in Question No. 9.

SUBJECT G.—*On Blasting, and the Use of Explosives.*

1. Give the temperature that dynamite freezes at, and state how you would thaw it.
2. Give the composition of blasting-powder, dynamite, and rackarock, and their relative strengths, taking blasting-powder at unity.
3. If a shot missed fire, what precautions would you adopt? What material would you use for tamping? Also, what material would you use as a tamping-bar? Give your reasons fully.
4. What effect, if any, has water on dynamite? and at what temperature does it explode?
5. How would you fire, say, five holes, in which gelatine was placed, simultaneously? and what precautions would you take so as to insure all the shots going off, supposing that the detonators in each instance were to be relied on as good?

SECOND DAY.—TIME: 2 P.M. TO 5 P.M.

SUBJECT E.—*On the Ventilation of Mines.*

1. What is meant by ventilation, and why is it required?
2. Give the composition of carbonic-acid, sulphuretted-hydrogen, and carburetted-hydrogen gases, and their effect on human life, and how they are detected in mines. Also give their percentage in the air of a mine that is deleterious to the health of the workmen employed.
3. If you had to circulate 15,000 cubic feet of air in a mine per minute, and divide it in four divisions—

1st one	6ft. by	6ft.,	1,500ft. long;
2nd "	6ft. "	5ft.,	1,400ft. "
3rd "	6ft. "	4ft. 6in.,	1,300ft. "
4th "	6ft. "	3ft.,	600ft. "

—assume the same pressure on each airway, and give the quantity of air passing through each.
4. If it requires a pressure of 4lb. per square foot to force a certain quantity of air through an airway 6ft. by 3ft., what pressure would be required to force the same quantity through an airway 4ft. 6in. by 4ft., both airways being of equal length?
5. Describe the different mechanical appliances you are acquainted with for ventilating mines.

THIRD DAY.—TIME: 9 A.M. TO 12 NOON.

SUBJECT J.—*A Knowledge of the different Rocks where Gold, Silver, Tin, Copper, Zinc, Lead, and Antimony are found, and on the Formation of Lodes and Leads.*

1. What metallic ores are usually associated with granite, gneiss, slate, propolyte, serpentine, and limestone respectively?
2. What is the composition of electrum, hessite, stephanite, proustite, galena, cerussite, chalcopyrite, tetrahedrite, stannine, brookite, wolfram, calamine, siderite, pyrrhotine, mispickel, braunite, diallogite, and chromite?

SUBJECT H.—*The Effect that Faults, Slides, and Mullock Bars have on Lodes, and how to ascertain the Direction of Slides and Heavals.*

1. Give six diagrams, with verbal explanations, to illustrate the effect that is exercised on mineral lodes by faults, slides, and mullock bars; and describe instances from personal observation.
2. Describe the application of Schmidt's law for the recovery of a lost lode.

THIRD DAY.—TIME: 2 P.M. TO 5 P.M.

SUBJECT I.—*A Knowledge of Underground Surveying, and the Making of Plans of Underground Workings, showing also the Dip or Inclination and Strike of the Reefs or Lodes.*

(*a.*) The candidate must produce a plan drawn to a scale not less than 5 chains to an inch, showing the surface boundaries of a mining claim not less than 20 acres in extent. The plan must also show the underground workings on the same plan, but in different-coloured inks. All traverse-lines on which the survey is based must be shown, with their bearings and lengths, all offsets to boundaries or other objects, together with the lines connecting the underground with the surface survey. The plan must have a north point, and the word "magnetic" or "true" written on it according to the meridian used. All traverses should be calculated from the starting-point. The plan must bear a certificate as follows: "I certify that the survey from which this plan has been drawn was done by myself, and that the plan is my own work also"; and it must be signed and dated. The area in acres must be shown.

(*b.*) The original field-notes of the survey must be produced, together with the tables of meridian and perpendicular distances (if any) for each traverse station in the survey: also produce a specimen of the method of calculations from which the positions have been derived. All of these must be signed by the candidate and dated.

(*c.*) Give a full description, in writing, of the method adopted in the survey, describing the initial point from which it was started, and show the close of the work, either in links or feet and the angular difference on closing. Describe how the inclined measurements were reduced to horizontal. State whether the true or what other meridian was used, and whether the same meridian was used both above and below ground.

(*d.*) Say what precautions were used to ascertain if the instrument was in adjustment, and how the length of the chain or tape was tested. What instrument was used for the angular measurements, and what for the linear measurements.

(*e.*) Draw a rough diagram to show how the surface and underground surveys were connected, and describe in writing the method adopted. State your opinion of the most accurate way of performing the above operation—first, when there is only one shaft; second, when there are two or more shafts.

FOURTH DAY.—TIME: 9 A.M. TO 12 NOON.

SUBJECT I (*continued*).—*A Knowledge of Underground Surveying, and the Making of Plans of Underground Workings, showing also the Dip or Inclination and Strike of the Reefs or Lodes.*

(*f.*) State whether the compass can be relied on for underground surveys, and give your reasons for the answer. If you had a choice of a compass or a theodolite, which would you use?

(*g.*) If you are obliged to make a magnetic underground survey, state what means you would use to check the correctness of the survey, and how you would know that the surface and underground survey are on the same meridian, or how you would reduce them to the same supposing one to be magnetic, the other true.

(*h.*) From the last station used in the underground survey, calculate the length and bearing of a line drawn thence to any one of the corners of the claim; or a line may be calculated from any one station of the surface survey to any one corner of the claim.

(*i.*) Describe in writing the adjustments of a plane theodolite and also of a miner's compass. (In both of these subjects the candidate will be examined by the Supervisor, who must furnish a separate report on each candidate's knowledge of the subject.)

(*j.*) Describe the method of plotting the plan, and how the area of the claim was ascertained, and what instruments were used.

(*k.*) What are the regulation marks that should define the boundaries of a claim under the Mines Act?

(*l.*) State where you learnt surveying, and who taught you, and how long you have had practice at surveying.

(*m.*) What are the sizes of posts required to mark out claims, and their height, according to the Mining Regulations?

FOURTH DAY.—TIME: 2 P.M. TO 5 P.M.

SUBJECT K.—*A Knowledge of Arithmetic and the Method of Keeping Accounts.*

1. What is the square of ·0004256? Also give the cube root of same number, and the value of $\cdot 000329^3$.

2. If seven men took four days and three hours in doing repairs in a shaft, the men's wages being 9s. per day, how long would it take four men and a boy to do the same work, the men's wages being 8s. per day and the boy's 5s., the boy doing only five-eighths of the quantity of work the men did? Also show the difference in cost.

3. If 414 tons of ore contained by assay 1oz. 3dwt. 4gr. of gold and 2·4dwt. of silver to the ton, and after battery treatment 31·5 per cent. of the gold was recovered and 26·7 per cent. of the silver, and the tailings from the battery were then worked in pans, and 60·4 per cent. of the gold in the tailings were obtained, and 57·1 per cent. of the silver, give the returns in gold and silver from the crushing.

4. If there were twenty-four men employed in a mine at 9s. per day, fifteen men at 8s. per day, and five boys at 5s. per day, and suppose the twenty-four men worked 3 days $4\frac{1}{2}$ hours each, the fifteen men 9 days $3\frac{3}{4}$ hours each, and the boys 11 days $1\frac{1}{2}$ hours each, what would their wages amount to?

5. Give an example of how you would make your entries in the day-book, cash-book, and ledger.

SUBJECT L.—*A Knowledge of Part VI. of "The Mining Act, 1891."*

QUESTIONS USED IN EXAMINATION OF MINING MANAGERS FOR SECOND-CLASS CERTIFICATES.

FIRST DAY.—TIME: 9 A.M. TO 12 NOON.

[Candidates must attempt to answer every question. All calculations to be shown in detail.]

SUBJECT *a.*—*The Laying-out and Construction of Shafts, Chambers, Main Drives or Levels, Uprises and Stopes.*

1. In laying out the position of a vertical shaft to work a lode dipping at an inclination of 60° eastward, if the outcrop of the lode was seen on the surface, state where you would sink the shaft in relation to the lode, giving your reasons fully.

2. In sinking an inclined shaft, what provision would you make for raising the excavated material to the surface, and what appliances would you use?

3. Give the dimensions of a main level or drive for a double line of rails, and also the dimensions of a chamber you would construct if there were sixty men employed in each shift below ground?

4. What is meant by a "pass"? What is its use, and how would you construct one?

5. If a quartz lode were dipping at an angle of 55°, and you were to sink a vertical shaft on the outcrop of the lode on the surface to a depth of 600ft., what distance would you have to drive from the bottom of the shaft to cut the lode?

SUBJECT *c.*—*On the Ventilation of Mines.*

1. What is meant by "ventilation"? Why is it required?

2. What gases are found in quartz mines? Give their composition, and state how you would detect their presence in a mine?

3. How is ventilation produced—(*a*) by natural means, (*b*) by mechanical means? State fully how you would produce it by both systems.

4. How would you ascertain when the air in a mine is deleterious and unfit for workmen to be employed therein?

FIRST DAY.—TIME: 2 P.M. TO 5 P.M.

SUBJECT *b.—On the Timbering of Shafts, Adits, Main Drives or Levels, Passes, Stopes, and generally on the Systems of Timbering Mines, and also in filling up Old Workings.*

1. Give the dimensions of timber for a main adit in heavy ground, (*a*) if for a double line of rails, (*b*) for a single line of rails. State how you would make each set, and what provision you would make if the ground was liable to swell. Give your reasons fully.
2. How far apart do you consider it most economical to have passes, and how would you timber them in heavy ground? Give dimensions of passes, and size of timbers.
3. Give the dimensions of planking you would use in timbering a shaft 4ft. by 10ft. in the clear; state how you would join the timber at the corners so as to make it thoroughly secure. Also give the dimensions of compartment if it were used for pumping and winding, and state how you would secure the guides for cages, and give their dimensions.
4. How would you secure the ground in stoping out a lode 6ft. wide, (*a*) timbering the stope, (*b*) to secure the ground after being stoped out?
5. Describe how you would secure the timber in a main adit so as to prevent more than two sets of laths coming down in the event of a cap breaking. Also give your reasons why all empty spaces should be filled up on the top of the laths.

SUBJECT *d.—Tapping Water in Mines.*

1. What precaution would you take if you were driving under a place where it was known there was a lodgment of water, and not more than 10ft. of solid ground overhead?
2. If you had to tap a lodgment of water by an uprise, what provisions would you make to secure the uprise and carry on the operations with safety?
3. In approaching a place where there was a lodgment of water by a drive or adit, and the ground was of a loose character, how would you secure it to render operations being carried on with safety? And state the precautions you would adopt in tapping the water.

SECOND DAY.—TIME: 9 A.M. TO 12 NOON.

SUBJECT *e.—On Blasting and the Use of Explosives.*

1. What explosive do you consider best for use in hard rock, or in stoping out a lode? Give your reasons fully.
2. What is the relative strength of dynamite, rackarock, and blasting-gelatine in comparison with blasting-powder?
3. Give the composition of the deleterious gases generated by the use of the following explosives: Blasting-powder, dynamite, rackarock, and blasting-gelatine.
4. What method would you use to thaw dynamite when in a frozen condition, and at what temperature does it freeze?
5. What explosive do you consider best to use in wet ground? Give your reasons fully.
6. If a shot were to miss fire, state what precautions you would take, and how you would proceed in blasting the rock.

SUBJECT *f.—A Knowledge of Arithmetic and the Method of keeping Accounts.*

1. If the wages of the workmen were £2 14s. per week of forty-eight hours, how much would the wages of 19 men working 2 weeks 4 days 3 hours amount to, 8 hours to be taken as a day's work?
2. If a piece of work took 1 man 22 days, who was paid at the rate of £2 12s. 6d. per week of forty-eight hours, how much would the work cost?
3. If the repairs to a main adit cost £40 16s. and took 2 men 51 days, how long would it take 7 men to accomplish the work, and what would be the difference in the cost if each of the 7 men were paid 9s. 6d. per day?
4. If the assay of ore gave 2oz. 16dwt. 12gr. of gold to the ton, and only 62 per cent. of that amount was recovered in the battery treatment, how much gold would be recovered from 125 tons of ore?
5. If the average thickness of a lode were 3ft. 2in., and a block were left 90ft. long and 45ft. high, how many cubic yards would it contain?

SUBJECT *g.—A Knowledge of Part VI. of "The Mining Act, 1891."*—Oral.

"THE COAL-MINES ACT, 1891."

QUESTIONS USED IN EXAMINATION OF MINING MANAGERS FOR FIRST-CLASS CERTIFICATES.

FIRST DAY.—TIME: 9 A.M. TO 12 NOON.

[Candidates must attempt to answer every question. All calculations to be shown in detail.]

SUBJECT I.—*On the Sinking of Shafts and Construction of Main Roadways, Opening out a Mine, and the Division of a Mine into Districts.*

1. What size would you make a rectangular shaft, 100 fathoms deep, up which 800 tons had to be wound in eight hours?
2. If necessary to open up a road through ground recently worked by longwall, how would you secure it?
3. Describe fully how you would sink a shallow rectangular shaft, say 60ft. in depth, through quicksand.
4. Give a sketch of your pit-bottom, and drawing-roads therefrom, in a coal-seam 6ft. thick, dipping south at 1 in 3, where the longer side of your shaft has a north-easterly bearing.

5. Give two different sizes which you would make the districts in opening up separate mines, and give the reasons fully for the difference.

SUBJECT II.—*The Various Methods adopted in Securing Shafts and Workings in a Mine, showing the relative Advantage and Efficiency of each Class of Material used.*

1. How would you secure your sets of timbering so that if one came away it should not bring others with it?
2. Give a sketch showing how you would secure your lining in sinking a rectangular shaft.
3. What is the relative strength of M. iron and timber used as cap-pieces?
4. What thickness of bricking would you put in in a 13ft. shaft at a depth of 500ft.? Would you pack behind it, and, if so, with what?
5. Give a formula for finding the thickness of C. I. tubbing, and explain its terms.

FIRST DAY.—TIME: 2 P.M. TO 5 P.M.

SUBJECT III.—*The Various Methods of Hewing and Cutting Coal of Different Classes to Advantage, and Securing the Ground whilst so engaged.*

1. Why are the roads sometimes driven at other than right angles to the levels in longwall workings, and what disadvantage does it entail?
2. In driving to cut a fault in steep measures, with a soft roof and hard floor, explain fully if it would make any difference if you met it on the level or in a dip drive.
3. Describe the system of working in any mine you are acquainted with, and mention if there is any improvement you can think of.
4. How would you work a 4ft. coal-seam with fireclay pavement and sandstone roof?
5. Has the amount of cover any bearing on the system adopted in working pillars? and, if so, explain fully in regard to depths of 60ft. and 600ft. respectively.

SUBJECT IV.—*The Various Methods of Ventilation, and the Construction of Airways so as to produce a Good Circulation of Fresh Air in any Part of a Mine.*

1. In a mine with one shaft 70ft. deep and another 110ft. deep, what is the direction of the air-current—(*a*) in summer, (*b*) in winter, with natural ventilation? Explain why.
2. Give the quantity of air in cubic feet per minute which a well-constructed furnace should circulate, as a general thing, for each foot in width of fire-bars; and enumerate the circumstances which modify this.
3. You have a furnace and steam-jet for ventilation, in a shaft 20 fathoms deep, which circulate 24,000 cubic feet of air per minute. When the furnace is out, only 8,000ft. circulate. How much would pass if only the furnace were used?
4. Describe and give sketch of the Mueseler safety-lamp.
5. If you double the length of an air-course, how much will the friction be increased?

SECOND DAY.—TIME: 9 A.M. TO 12 NOON.

SUBJECT V.—*On the Areas of Airways, the Velocity and Divisions of Currents, and the Deductions to be made for Friction.*

1. Give a sketch in section of a ventilating-furnace, and its position in relation to the upcast shaft.
2. Thirty thousand cubic feet of air are passing in two splits: how much circulates in each if one measures 7ft. by 4ft. and the other 7ft. by 8ft.?
3. Give a description of the Capell fan, and state what you know of it as a ventilating-machine.
4. At a fiery mine, ventilated by a fan, what safeguard should be provided against the break-down of the fan-engine?
5. What are the uses of the barometer at fiery mines?

SUBJECT VI.—*On the Nature and Composition of Explosive and Dangerous Gases occurring in Coal-mines, and on Spontaneous Combustion.*

1. What is the composition of heavy carburetted hydrogen? Is it more dangerous than the ordinary firedamp or not?
2. Can a gas which burns be a non-supporter of combustion?
3. In workings where you suspected a tendency to spontaneous combustion, what steps would you take to ascertain if it were in progress?
4. What is the composition of white-damp?
5. What is the temperature of ignition of firedamp?

SECOND DAY.—TIME: 2 P.M. TO 5 P.M.

SUBJECT VII.—*On the Drainage of Mines, and Pumping Appliances.*

1. Give a sketch of an ordinary bucket, in plan and section.
2. In what circumstances should the pump-rods and weight of water in the pipes be equal? Give a case in which they should not, and state which should be heavier, and why?
3. What size of spears would you use for 20in. pumps?
4. What pressure per square inch will be caused by a head of 50 fathoms of water, and what thickness of metal would be needed for the pipes?
5. Give a full description of a centrifugal pump.
6. Describe the air-vessel and its uses for a forcing-pump.

SUBJECT VIII.—*The Haulage on Planes and in Shafts, also the Different Systems of Underground Haulage, with Horse-power required to do the Work.*

1. You have to wind 1,100 tons in ten hours from a depth of 80 fathoms: what horse-power is required to do the work, and what size cylinders would you fit up? Show fully how you arrive at your results.
2. An engine weighing 8 tons can draw a load of 60 tons on the level, the coefficient of friction being 160lb. per ton: what can it draw up an incline of 1 in 25?
3. State the reasons for and against loose wheels, also for those fast on the axle.
4. Give a sketch of your arrangements for rope and boxes where a branch curves off in endless-rope haulage.

THIRD DAY.—TIME: 9 A.M. TO 12 NOON.

SUBJECT IX.—*The Theoretical and Effective Power of Steam-engines and Boilers; also, on the Strength of Hauling-ropes and -chains.*

1. Give a sketch, in section, of a Lancashire boiler fitted with Galloway tubes, and detail the advantages of the latter.
2. What size of cylinder is needed to give 60 I. H. P. with 57lb. mean pressure and 210ft. travel per minute?
3. Give a sketch of a safety-valve, and describe its action.
4. What is the bursting-pressure of a boiler 28ft. long, 6ft. diameter, and $\frac{5}{8}$in. plates, with tensile strength 55,000?
5. What is the breaking-strain of a steel-wire rope 2$\frac{1}{2}$in. in circumference?

SUBJECT X.—*The Incrustations in Steam-boilers and Cause of Same, and the Remedy therefor.*

1. How would you introduce a remedy for incrustations into a boiler?
2. What are the causes of corrosion in a boiler?
3. What remedy would you use for sulphate of lime in the feed-water of a boiler?

THIRD DAY.—TIME: 2 P.M. TO 5 P.M.

SUBJECT XI.—*Tapping Water in Mines, and the Mode of constructing Dams in Underground Workings to keep Water back.*

1. Describe how you would put in a brick dam to withstand a heavy pressure, and give dimensions.
2. State the precautions you would adopt in approaching a large body of water overhead.

SUBJECT XII.—*Blasting, and Use of Explosives.*

1. State fully whether you think it would be desirable or not to use high explosives in place of powder in bringing down coal.
2. State what you know of water as tamping for dynamite.
3. What is the composition of gelignite?
4. To what points would you direct your attention to prevent accidents from blasting in a mine of which you had charge?

SUBJECT XIII.—*The Effect that Faults produce in Coal-seams, and how to ascertain the Direction of a Coal-seam when severed by a Fault.*

1. In prospecting a coalfield broken by granite, would it be material to find out whether the coal was deposited round the granite ridges, or if the latter had broken through the bedded rocks? How would you determine the point?
2. Give sketches of ordinary and reversed faults.
3. How would you ascertain the direction of a coal-seam when severed by a fault?
4. Describe fully what a "roll" in a coal-seam is, and state if it has any connection with faulting.
5. In your experience, have you ever found a fault produce a good effect on the quality of coal in a seam which it had severed? If so, describe it, and give your explanation.

FOURTH DAY.—TIME: 9 A.M. TO 12 NOON.

SUBJECT XV.—*A Knowledge of Surface and Underground Surveying, and of making Plans, showing System of Working, Inclination of Seam, Faults, and System of Ventilation.*

1. The candidate must produce a plan showing the style of workings in a colliery, with the surface taken up for at least 20 acres in the vicinity of the shaft, and the underground workings in different-coloured ink. He must describe how he would connect them with the surface in the event of there being only one shaft. The levels and main heading must have assumed traverse, calculated in detail, and showing latitude and departure for each bearing.
2. A bore has been put down N. 40° E. and 20 chains distant from your mine-mouth, whence the stone mine dips at 10°, bearing N. 12° W., distant 8 chains; thence in the coal-seam, which is level, N. 7° E., 240 links; N. 2° W., 150 links; N. 15° E., 300 links: what distance have you to drive to strike the borehole, and on what bearing?
3. How would you ascertain if the sights in a dial were truly vertical and their supports correct? If they were not, would they cause the survey to be inaccurate?
4. Explain the reading of the vernier scale on a theodolite.

5. Give a sketch of a few of the workings of a mine, showing how you would keep your survey-book, with bearings, distances, dip, width of places, and thicknesses of coal entered.
6. Describe the clinometer.

SUBJECT XVI.—*A Knowledge of Arithmetic, and the Method of keeping Accounts.*

1. What is the $\sqrt{705,600}$ and the $\sqrt[3]{594,823,321}$?
2. Divide $\frac{1}{3}$ by $\frac{7}{6}$ of $\frac{1}{4}$.
3. If you know the lengths of the three sides of a triangle, how would you find its area?
4. Explain what you know of the method of keeping accounts.
5. A heap of coal measures 200 yards by 25 yards at the base, and is 12ft. high: how many tons does it contain?
6. How many tons of coal does a pillar 42ft. by 60ft. by 9ft. contain?
7. How much does the royalty on 170,531 tons amount to at 6½d. per ton?
8. If 22½ cwt. were taken instead of 20 cwt. to the ton, in the last question, what would the amount come to?

SUBJECT XVII.—*A Knowledge of the Provisions of "The Coal-mines Act, 1891."*

FOURTH DAY.—TIME: 2 P.M. TO 5 P.M.

SUBJECT XIV.—*A Knowledge of the Composition and Character of the Different Classes of Coal, and also of the Character of the Rocks and Formation of the Country where Coal is likely to be found.*

1. If you came upon schist rock in prospecting for coal, would you consider it necessary to abandon operations?
2. Give the proximate analysis of a bituminous coal.
3. State the circumstances in which you would consider a pure-white sand (*a*) a favourable and (*b*) an unfavourable indication of the presence of coal.
4. Describe the characteristics of a cannel coal.
5. Are the brown or pitch coals of the East Coast of the same age as the bituminous coals of the West Coast? If so, give the reasons why the one should be bituminous and the other not.

"THE COAL-MINES ACT, 1891."

QUESTIONS USED IN EXAMINATION OF MINING MANAGERS FOR SECOND-CLASS CERTIFICATES.

FIRST DAY.—TIME: 7 A.M. TO 12 NOON.

[Candidates must attempt to answer every question. All calculations to be shown in detail.]

SUBJECT I.—*On the Sinking of Shafts and Construction of Main Roadways, Opening out a Mine, and the Division of a Mine into Districts.*

1. What considerations would guide you in fixing the position of a shaft to open up a coal-field?
2. Describe fully all your operations in sinking to the stone head. Assume conditions.
3. Give sizes of all timber used in fitting a rectangular shaft, $6' \times 14' \times 135'$, in fairly strong measures.
4. What considerations would guide you in fixing the size of the districts in a mine?

SUBJECT II.—*The various Methods adopted in Securing Shafts and Workings in a Mine, showing the relative Advantage and Efficiency of each Class of Material used.*

1. In a cap 10″ deep by 8″ broad, what reason is there for the extra depth? Would you adopt that form; and, if so, in what circumstances?
2. Sketch how you would support the lining at the bottom of a rectangular shaft.
3. Describe how you would support the roof near the face in working a 5ft. seam by longwall. Give dimensions.
4. What are the chief disadvantages of the circular form in shafts?
5. What kind of timber would you use for lining a wet shaft, and what for pump-rods.

FIRST DAY.—TIME: 2 P.M. TO 5 P.M.

SUBJECT III.—*The various Methods of Hewing and Cutting Coal of Different Classes to Advantage, and Securing the Ground whilst so engaged.*

1. If you had an area of 30 acres in pillars, and the roof was not standing well, describe your method of working it. Thickness of coal, 10ft.
2. In working out 18ft. of coal and having coal roof, what method would you adopt to work the upper part of the 18ft., and how prevent accidents from falls of the roof thereafter?
3. State how you would work a 5ft. seam with strong shale roof and weak floor.
4. What size of pillar would you leave to protect a shaft 80 fathoms deep? Coal seam 10ft. thick, and lying at 1 in 8.

SUBJECT IV.—*The various Methods of Ventilation, and the Construction of Airways so as to produce a Good Circulation of Fresh Air in any part of a Mine.*

1. Draw to scale a good air-crossing.
2. If the volume of air be trebled, how much will the friction be increased?

3. Explain fully how you would put up your brattice-cloth.
4. How would you ventilate a shaft in which a little black-damp was met with in sinking?
5. In splitting the air, how would you provide that one district did not get too much?

SECOND DAY.—TIME: 9 A.M. TO 12 NOON.

SUBJECT V.—*On the Areas of Airways, the Velocity and Divisions of Currents, and the Deductions to be made for Friction.*

1. Is anything else than an increased current gained by splitting the air?
2. Would you unite all your return air-currents as soon after passing the men as possible in an extensive mine free from gas?
3. You have an air-course 20ft. by 10ft. which must be allowed to close: what size must two smaller air-ways of equal size be to give the same volume of air?
4. State the different reasons that would guide you in regulating the velocity of the currents in a fiery mine.
5. What does one inch of water-gauge mean?

SUBJECT VI.—*On the Nature and Composition of Explosive and Dangerous Gases occurring in Coal-mines, and on Spontaneous Combustion.*

1. Describe the various properties of carbonic acid gas.
2. What proportions of fire-damp and air cease to be explosive?
3. What is the composition of after-damp?
4. Describe the Marsaut safety-lamp.
5. Are all coals liable to spontaneous combustion? Explain as fully as you can.

SECOND DAY.—TIME: 2 P.M. TO 5 P.M.

SUBJECT VII.—*On the Drainage of Mines, and Pumping Appliances.*

1. What is the greatest depth for a single lift, and what causes limit this?
2. Is there more wear and tear with a forcing or lifting pump? Explain why.
3. Sketch the arrangements at the junction of a plunger and lifting-set.
4. What arrangements would you make for pumping very sandy water?

SUBJECT VIII.—*The Haulage on Planes and in Shafts, also the Different Systems of Underground Haulage, with Horse-power required to do the Work; also on the strength of Hauling-ropes and Chains.*

1. What is the limit to the length of one section of an endless rope? Give an example.
2. Give sketch of self-acting incline, where the roof is so bad that you cannot have a double line of rails except in the middle, and describe arrangements for tubs passing.
3. Describe and give sketch of the method by which you would keep an endless rope from becoming slack.
4. How would you attach the tubs to an endless chain, where the thinness of the seam compelled it to be done underneath the box? Give sketch.

THIRD DAY.—TIME: 9 A.M. to 12 NOON.

SUBJECT IX.—*Tapping Water in Mines, and the Mode of Constructing Dams in Underground Workings to keep Water back.*

1. Give sketch in plan, with sizes marked, of the dam you would put in for a heavy head of water.
2. What arrangements would you make for preventing too great an outflow of water from the bore-hole in tapping a body of water under great pressure?
3. What is the greatest width you would permit a place approaching a heavy body of water to be?

SUBJECT X.—*Blasting and the Use of Explosives.*

1. What is the chief objection to the use of powder in mines?
2. Why should another hole not be drilled near any one in which any charge of a nitro-glycerine explosive has missed fire?
3. What are the uses of the water cartridge?

THIRD DAY—TIME: 2 P.M. TO 5 P.M.

SUBJECT XI.—*The Effect that Faults produce in Coal-seams, and How to Ascertain the Direction of a Coal-seam when severed by a Fault.*

1. What is meant by a step fault, and what does it indicate?
2. What reasons are there for coal being of inferior quality near faults?
3. In what circumstances would you look for a reversed fault?
4. Show by sketch how you would measure the amount of displacement caused by a fault in an inclined seam?

SUBJECT XII.—*A Knowledge of Arithmetic, and the Method of Keeping Accounts.*

1. How many cubic feet would be excavated in sinking a shaft 12ft. diameter for a depth of 160ft.?

2. A brick wall is 900 square feet, and one half-brick in thickness: how many bricks does it contain?

3. Five men at 13s., two at 12s., and nineteen at 10s. 6d. per day: what will the amount of the week's pay be?

4. What is the square root of 1,156?

SUBJECT XIII.—*A Knowledge of the Provisions of "The Coal-mines Act, 1891."*

QUESTIONS USED IN EXAMINATION FOR CERTIFICATES AS ENGINE-DRIVERS WORKING WINDING-MACHINERY.

FIRST DAY.—TIME: 9 A.M. TO 12 NOON.

[Candidates must attempt to answer every question. All calculations to be shown in detail.]

SUBJECT 1.

On the Different Classes of Steam-engines used in Winding; and also all the Internal and Moving Parts.

No. 1. Mention all the different types of steam-engines used for winding.

No. 2. Describe a piston; mention all its parts and their respective uses.

No. 3. How would you ascertain if your piston was steam-tight?

No. 4. Describe a feed-pump; mention all its parts, and for what purpose each part is required.

No. 5. If feed-pump failed to work, what part would you examine for defects?

No. 6. What speed per minute do you consider it safe to wind men up a shaft, and what speed material?

No. 7. In what respect does a winding-engine differ from an ordinary steam-engine?

No. 8. Describe a slide-valve—where placed, how driven, and for what purpose it is required.

No. 9. Describe in detail all you consider an engine-driver should do before starting a winding-engine.

SUBJECT 2.

On the Different Appliances and Indicators used to show the Position of Cage in Shaft, or Truck on Plane, in which Persons are conveyed; also Meaning of the different Signals used in Mines.

No. 1. How is the position of cage in shaft, or truck on plane, made known to engine-driver?

No. 2. Describe an indicator which complies with the above conditions.

No. 3. Describe the methods of signalling from different parts of the shaft to the engine-driver.

No. 4. Describe the different methods of signalling from any part of a plane to the engine-driver.

No. 5. What are the regulations under the Coal-mines Act when the cage is required to lift, stop, and lower—and if any difference when drawing men or material?

No. 6. Describe any other methods of signalling you are acquainted with.

FIRST DAY.—TIME: 2 P.M. TO 5 P.M.

SUBJECT 3.

On the Different Kinds of Boilers used for Winding-engines and their Connections; the Effect of Impurities in Water used in such Boilers; and the different Remedies adopted to keep them Clean.

No. 1. Describe a Lancashire boiler.

No. 2. Mention all the necessary fittings and mountings required for a Lancashire boiler.

No. 3. Give a description of a low-water alarm.

No. 4. What are fusible plugs, where fitted, and for what purpose?

No. 5. If water became dangerously low in a boiler at work, what precautions would you adopt to prevent an accident?

No. 6. What would be the result if your feed-check got set fast with valve open? also, if valve was shut?

No. 7. What parts of a Cornish or Lancashire boiler require special attention if the water used is impure?

No. 8. What ingredients would be required to remove the impurities in a boiler using limestone water?

SUBJECT 4.

On the Different Appliances used for Winding with Hydraulic Machinery, and the Methods adopted for letting on and shutting off the Water.

No. 1. In what respect does a reversing wheel differ from an ordinary wheel?

No. 2. Is a brake necessary on a reversing wheel; if so, where should it be placed?

No. 3. Can a Pelton wheel be used for winding; if so, what gear, if any, is necessary for its adoption?

No. 4. Can a turbine wheel be used for winding; if so, what is required for its adoption?

No. 5. What is a sluice-valve, where fitted, and for what purpose?

SECOND DAY.—TIME: 9 A.M. TO 12 NOON.

SUBJECT 5.

On the Power of Steam-engines and Hydraulic Machinery.

No. 1. What is a horse-power?
No. 2. What is a Government head of water?
No. 3. What is the horse-power of twenty-five heads of water falling 120ft.?
No. 4. Give the average efficiency of the Pelton, overshot, breast, and undershot wheels.
No. 5. What is the required height of a column of water to be equal to 156lb. per square inch?
No. 6. What direct weight would be required on a safety-valve to give 95lb. per square inch—diameter of valve, 3in.?
No. 7. What would be the pressure on a boiler with a safety-valve 4in. diameter, distance from fulcrum to valve 4in., and from fulcrum to weight 36in., and weight 112lb. (neglecting weight of lever and valve)?
No. 8. What would be the indicated horse-power of an engine whose diameter of cylinder was 22in., stroke 4ft., making 85 revolutions per minute, mean pressure 34lb. per square inch?

SUBJECT 6.

On the Prevention of Priming in Boilers.

No. 1. What is meant by boilers priming?
No. 2. Is there any danger to machinery from priming?
No. 3. Is there any danger to boilers from priming?
No. 4. State what precautions are necessary with machinery when boilers prime.
No. 5. Mention all the causes conducive to priming.
No. 6. What remedies or precautions would you adopt to prevent priming?

LIST OF MINING MANAGERS AND ENGINE-DRIVERS WHO HAVE OBTAINED CERTIFICATES UNDER THE MINING AND COAL-MINES ACTS OF 1886 AND 1891.

As there have been several inquiries made as to the names of persons who hold certificates as mine-managers and engine-drivers, the annexed is a complete list of those holding certificates at the date of this report, taken from the register:—

THE MINING ACT.

FIRST-CLASS SERVICE CERTIFICATES.

Issued under "The Mining Act, 1886," without Examination.

Adams, H. H., Waiorongomai.
Anderson, P., Thames.
Andrews, T., Thames.
Andrews, R., Coromandel.
Barclay, T. H., Thames.
Bennett, J., Alexandra.
Benney, J., Coromandel.
Black, T., Waiomai.
Bollersley, N., Boatman's.
Bradbury, M., Reefton.
Bray, John, Lyell.
Burch, W. H., Thames.
Byrne, J. F., Stafford.
Cameron, A., Macetown.
Cameron, E., Te Aroha.
Chapman, J. A., Dunedin.
Clarke, G. S., Thames.
Comer, R., Thames.
Conradson, M., Thames.
Corin, W., Thames.
Cornes, C. A., Karangahake.
Coutts, J., Thames.
Crawford, T. H., Thames.
Crowley, C., Reefton.
Cummings, W., Reefton.
Davis, J. E., Queenstown.
Davey, C., Ross.
Donald, J., Cromwell.
Dryden, S., Thames.
Dunlop, T. A., Thames.
Edwards, J., Skippers.
Elliott, J., Macetown.
Evans, F., Skippers.
Evans, J. H., Skippers.
Fitzmaurice, R., Reefton.
Frewen, J. B., Queenstown.
Gavin, T., Te Aroha.
Gilbert, J., Reefton.
Gilmour, T., Thames.
Giles, G. F., West Wanganui.
Glass, W. M., Naseby.
Goldsworthy, J., Waiorongomai.
Greenish, J., Reefton.
Greenville, W., Ohinemuri.
Hall, J. P., Thames.
Hansen, P. C., Thames.
Harris, J., Owen's Reefs.
Harrison, R. H., Coromandel.
Hicks, T. B., Thames.
Hilton, G. P., Bendigo.
Hodge, F., Coromandel.
Hollis, W., Thames.
Hunter, R., Thames.
James, F., Thames.
Jamieson, A., Coromandel.
Jenkins, M., Wakatipu.
Johnstone, H., Bluespur.
Julian, J., Boatman's.
Kelly, J., Lyell.
Kerr, J., Thames.
Lawn, E., Black's Point.
Lawn, H., Boatman's.
Lawn, J., Reefton.
Littlejohn, W., Karangahake.
Lowe, E. W., Thames.
Malfroy, J. M. C., Ross.
Martin, W. G., Thames.
McCullum, J., Reefton.
McCullough, R., Thames.
McGruer, N., Karangahake.
McIlhaney, J., Thames.
McIntosh, D., Bluespur.
McKay, J., Ross.
McKenney, J., Reefton.
McKenzie, W., Thames.
McLeod, G., Coromandel.
McLiver, F., Thames.
McLiver, H., Thames.
McMaster, J., Reefton.
Moore, H. W., Thames.
Moore, J. H., Thames.
Morgan, R., Otago.
Morrisby, A. A., Glenorchy.
Nasmyth, T., Reefton.
Newman, W., Naseby.
Northey, J., Thames.
O'Sullivan, D. E., Thames.
Polton, A., Karangahake.
Porter, J., Waipori.
Purvis, G., Ross.
Quinn, E., Te Aroha.
Radford, T., Thames.
Ralph, J. G., Thames.
Ranger, J., Reefton.
Rasmussen, C. L., Mokihinui.
Rasmussen, C. P., Mokihinui.
Reid, P., Coromandel.
Resta, L., Macetown.
Roberts, E., Ross.
Rooney, F., Reefton.
Scott, T., Waiorongomai.
Searight, A., Reefton.
Senior, J., Thames.
Smith, J. E., Thames.
Stone, F., Karangahake.
Steedman, J. B., Thames.
Sturm, A., Waipori.
Taylor, N., Thames.
Todd, C., Heriot.
Treloer, J. S., Reefton.
Tripp, R. S., Arrowtown.
Vivian, J. G., Thames.
Vivian, S., Reefton.
Waite, C. D., Thames.
Waite, E., Thames.
Walker, J. W., Thames.
Watson, T., Reefton.
Wearne, J. E., Endeavour Inlet.
Wilcox, J., Thames.
Williams, J., Skippers.
Wright, G., Boatman's.
Wylie, W., Ross.
Young, G., Skippers.

First-class Mine-managers' Certificates, issued after Examination, under "The Mining Act, 1886," and Amendment Acts.

Adams, B., Thames.
Baker, W., Thames.
Black, G., Reefton.
Caples, P. Q., Dunedin.
Carter, J., Thames.
Casley, G., Reefton.
Cochrane, D. L., Reefton.
Colebrook, J. D., Coromandel.
Coombe, J., Reefton.
Crawford, J. J., Thames.
Cummings, W., Reefton.
Donaldson, W., Otago.
Fleming, M., Thames.
Gardner, W. P., Reefton.
Harris, W., Thames.
Horn, G. W., Thames.
Horne, W., Coromandel.
Hornick, M., Thames.
Hosking, G. F., Auckland.
Kruizenza, W., Reefton.
Lawn, T., Reefton.
Logan, H. F., Wellington.
Mangan, T., Thames.
Mouat, W. G., Dunedin.
Truscott, G., Thames.
Watkins, C. E., Reefton.
Wilkie, J., Reefton.

First-class Mine-manager's Certificate, issued on production of Foreign Certificate, under "The Mining Act, 1886."

Argall, W. H., Coromandel.

First-class Mine-manager's Certificate, issued to Inspector of Mines by virtue of his office under "The Mining Act, 1886."

Binns, G. J., Dunedin.

First-class Mine-managers' Certificates, issued after Examination, under "The Mining Act, 1891."

Annear, William, Reefton.
Bray, E., Thames.
Bruce, Malcolm, Thames.
Fahey, P., Reefton.
Flannigan, Francis, Reefton.
Lawn, C. H., Capleston.
Link, F. W., Thames.
McDermott, J., Thames.
Paul, Matthew, Thames.
Paltridge, Henry, Thames.
Robertson, D. B., Stafford.
Stanford, W. J., Macetown.
Steedman, J. G., Thames.
Sutherland, Benjamin, Reefton.
Tierney, R., Thames.
Warne, George, Thames.
Williams, C., Capleston.

SECOND-CLASS SERVICE CERTIFICATES AS MINE-MANAGERS.

Issued under "The Mining Act, 1891."

Adams, W. J., Thames.
Allen, Richard, Reefton.
Argall, A. E., Coromandel.
Bennett, C. H., Coromandel.
Begley, Thomas, Reefton.
Beard, W. T., Reefton.
Bone, William, Reefton.
Bowler, John, Thames.
Blair, Thomas, Kuaotunu.
Bray, Edwin, Reefton.
Brownlee, Thomas James, Thames.
Brokenshire, James, Thames.
Bolitho, James, Reefton.
Brown, John, Macrae's.
Bremner, John, Coromandel.
Borlase, J. H., Capleston.
Bunny, Joseph, Thames.
Byrne, John, Karangahake.
Caird, Alexander McNeil, Reefton.
Campbell, J., Kuaotunu.
Climo, Noah, Coromandel.
Comer, George, Thames.
Cowan, Hugh, Kuaotunu.
Corbett, T., Paeroa.
Comer, W. W., Thames.
Crabb, Thomas, Reefton.
Daniel, P. F., Greymouth.
Dobson, John Allen, Kuaotunu.
Edwards, George, Westport.
Ellery, John, Reefton.
Flannigan, Francis, Reefton.
Foster, Thomas, Wellington.
Gale, C. W., Coromandel.
Gill, George, Thames.
Glasgow, T. M., Thames.
Goldsworthy, Henry, Thames.
Govan, Joseph, Thames.
Griffin, Patrick, Thames.
Grimmond, Joseph, Ross.
Goldsworthy, William, Mauku, Auckland.
Gemmings, Charles, Thames.
Gribble, James, Norsewood.
Guthrie, John, Wellington.
Guy, Robert, Kuaotunu.
Harris, Richard, Thames.
Harvey, William, Reefton.
Hardman, James Edward, Thames.
Hicks, William, Thames.
Hetherington, William, Thames.
Hill, Alex. Grey, Waikakaho.
Hore, John, Wellington.
Hollis, Fred. J., Waihi.
Hornibrook, H. P., Kuaotunu.
Jamieson, John, Reefton.
Johnstone, William, Collingwood.
Jobe, James, Thames.
Johns, Thomas, Thames.
Kendall, Henry, Thames.
Kerr, George, Kamo.
Kirker, Thomas, Thames.
Laughlin, David, Thames.
Law, John, Thames.
Loughlin, S., Thames.
Lough, Henry, Thames.
McLean, James, Thames.
McLean, Alex., Coromandel.
McLean, Charles, Thames.
McCormick, Charles, Coromandel.
McQuillan, John, Reefton.
McNeill, Daniel, Thames.
McNeill, George, Upper Kuaotunu.
McCombie, John, Karangahake.
McEwen, James, Reefton.
McLoghry, Archibald, Karangahake.
Mackay, William, Nenthorn.
Martin, James, Reefton.
Meagher, John, Karangahake.
Mills, George, Thames.
Mayn, John, Coromandel.
Martin, David, Black's Point.
Morgan, William, Upper Thames.
Moorecroft, Thomas, Thames.
Milne, John, Thames.
Moyle, Thomas, Thames.
Naysmith, James, Reefton.
Newdick, Alfred, Thames.
Notman, Alexander, Reefton.
O'Keefe, M. W. D., Thames.
Page, John, Lyell.
Parkiss, Jos. W., Reefton.
Potts, W. H., Thames.
Primrose, J., Kuaotunu.
Pettigrew, Robert, Sydney.
Peebles, Alexander, Kuaotunu.
Pollock, John, Thames.
Phillips, William Henry, Thames.
Rabe, Henry, Thames.
Reid, Thomas Groat, Thames.
Richard, John, Thames.
Rickards, A. H., Kuaotunu.
Radford, Thomas, Thames.
Rogers, Charles Henry, Reefton.
Rogers, William Henry, Kumara.
Ross, J., Thames.
Rowe, James, Thames.
Shaw, James, Karangahake.
Sligo, Alex., Nenthorn.
Thomas, James, Thames.
Thomas, A., Thames.
Thomson, John, Dunedin.
Tregellas, James, Reefton.
Tregoweth, William, Thames.
Wells, Charles Lewis, Thames.
Willets, Henry, Thames.
Williams, James, Thames.
Williams, John, Thames.
Whisker, Charles, Thames.
White, John S., Karangahake.
Wilson, James R. S., Kuaotunu.
Wilson, J. G., Thames.
Woodcock, James, Thames.
Worth, Robert, Waihi.

ENGINE-DRIVERS' SERVICE CERTIFICATES.

Issued under "The Mining Act, 1891."

Audley, F., Coromandel.
Battens, H., Coromandel.
Black, C., Reefton.
Black, G. J., Reefton.
Bridson, Mat. J., Thames.
Casley, J., Thames.
Clerkin, F., Reefton.
Crabb, J., Reefton.
Crofts, J. W., Skipper's.
Cook, W., Thames.
Craig, D., Thames.
Davies, T., Thames.
Dunstan, J., Thames.
Faithful, William, sen., Cromwell.
Faithful, William, jun., Cromwell.
FitzMaurice, Raymond, Reefton.
Grundy, T., Thames.
Harrison, R. H., Kuaotunu.
Hope, J. S., Waitekauri.
Hufton, George, Reefton.
Ivey, R., Thames.
Latimer, Alfred, Dunedin.
Lamberton, J., Reefton.
Lawn, E., Reefton.
McLean, J., Reefton.
Milne, S., Coromandel.
Murphy, A. R., Queenstown.
Morton, C., Thames.
Patterson, D., Reefton.
Patten, A. C., Reefton.
Phillips, W. H., Thames.
Ryan, J. P., Coromandel.
Roche, H., Thames.
Saunders, William, Reefton.
Smith, R., Thames.
Skilton, A. G., Westport.
Sullivan, W., Coromandel.
Titley, A. W., Black's Point.
Walding, J., sen., Coromandel.
Walding, J., jun., Coromandel.
Warne, G., Thames.
Wishart, R., Thames.
Wood, A., Thames.

Engine-drivers' Certificates issued after Examination under "The Mining Act, 1891."

Allen, A., Thames.
Auld, James, Reefton.
Blackadder, D., Reefton.
Daldy, E. A., Coromandel.
Dunstan, I., Waihi.
Elliston, A. J., Reefton.
Lawn, C. H., Capleston.
McAuley, T., Reefton (for water).
Ross, M., Reefton.
Slowey, William, Reefton.
Wilson, F. H., Thames.
Wynn, M., jun., Reefton (for water).

THE COAL-MINES ACT.

First-class Mine-managers' Certificates.

Issued under the Coal-mines Acts, 1886 and 1891.

Aitken, T., Wendon.
Alexander, T., Brunnerton.
Austin, J., Sheffield.
Bishop, J., Brunnerton.
Brown, T., Westport.
Brown, T., Glentunnel.
Cameron, J., Denniston.
Campbell, J. C., Fairfield.
Collins, W., Taupiri.
Dando, M., Brunnerton.
Elliott, R., Wallsend.
Ferguson, A., Whitecliffs.
Freeman, J., Green Island.
Geary, J., Kamo.
Gray, J., Abbotsford.
Harrison, J., Brunnerton.
Irving, J., Kaitangata.
Jemison, W., Waimangaroa.
Kenyon, J., Shag Point.
Kerr, G., Kamo.
Lindop, A. B., Springfield.
Lindsay, W., Otago.
Lloyd, J., Invercargill.
Louden, J., Green Island.
Love, A., Whangarei.
Mason, J., Nightcaps.
May, J., Greymouth.
Moody, T. P., Kawakawa.
Moore, W. J., Springfield.
Nelson, J., Green Island.
Ord, J., Huntly.
Redshaw, W., Whangarei.
Reed, F., Westport.
Richardson, D., Abbotsford.
Shore, J., Kaitangata.
Shore, T., Orepuki.
Shore, W. M., Kaitangata.
Smart, W., Christchurch.
Smith, A. E., Nelson.
Smith, T. F., Nelson.
Sneddon, J., Mosgiel.
Swinbanks, J., Kawakawa.
Taylor, E. B., Huntly.
Thompson, A., Whitecliffs.
Walker, J., Collingwood.
Williams, W. H., Shag Point.

Certificates issued after Examination under "The Coal-mines Act, 1886," and 1891.

First-class.	First-class.	Second-class.
Armitage, F. W., Auckland.	Hosking, G. F., Auckland.	Barclay, T., Kaitangata.
Gibson, John, Westport	Jebson, D., Canterbury.	Lindsay, J. B., Orepuki.
Green, E. R., Abbotsford.	Milligan, N., Thames.	Snow, T., Mercer.
Green, J., Brunnerton.		

First-class Mine-managers' Certificates issued on production of English Certificate, under "The Coal-mines Act, 1886."

Binns, G. J., Dunedin.
Black, T. H., Waipori.
Broome, G. H., Ngakawau.
Cater, T., Auckland.
Cochrane, N. D., Dunedin.
Garrett, J. H., Auckland.
Hayes, J., Kaitangata.
Hodgson, J. W., Ross.
Macalister, J., Invercargill.
Nimmo, J., Oamaru.
Straw, M., Westport.
Tattley, W., Auckland.

First-class Mine-managers' Certificates issued to Inspectors of Mines by virtue of office under "The Mining Act, 1886," and "The Coal-mines Act, 1886."

Cochrane, N. D., Westport.
Gordon, H. A., Wellington.
Gow, J., Dunedin.
McLaren, J. M., Thames.
Wilson, G., Thames.

Mine-managers' Service Certificates (Foreign).

Issued under "The Coal-mines Act, 1886."

Irvine, James, Dunedin.
Jordan, R. S., Kaitangata.
Lewis, W., Blackball.
Proud, Joseph, Wanganui.

Second-class Mine-managers' Service Certificates.

Issued under "The Coal-mines Act, 1891."

Carson, M., Kaitangata.
Collier, Levi, Kamo.
Clarke, Edward, Shag Point.
Elliot, Joseph, Coal Creek.
Harris, John, Denniston.
Herd, Joseph, Brunnerton.
Howie, James, Kaitangata.
Leeming, William, Whitecliffs.
Lobb, Joseph, Mokau.
Love, Alexander, Orepuki.
McIntosh, Allan, Shag Point.
Marshall, J., Ngakawau.
Murray, Thomas, Denniston.
Nimmo, George Stewart, Ngapara.
Radcliffe, William, Reefton.
Roberts, John, Brunnerton.
Sara, James, Reefton.
Ross, John, Kawakawa.
Smith, Charles, Whangarei.
Thomas, James, Springfield.
Wallace, William, Huntly.
Willetts, John, Papakaio.
Willetts, John Morris, Papakaio.
Young, William, Waimangaroa.

Engine-drivers' Certificates.

Issued under "The Coal-mines Act, 1886."

Bainbridge, William, Brunnerton.
Beirn, William H., Kaitangata.
Clark, A., Kaitangata.
Davidson, Robert, Walton Park.
Elliott, R., Denniston.
Eltringham, Stephen, Greymouth.
Foote, Thomas, Miranda.
Gall, Adam, Huntly.
Gill, Robert, Shag Point.
Gillies, D., Walton Park.
Girven, Adam, Kawakawa.
Grundy, Walter, Kamo.
Gibson, J., Denniston.
Gray, G. A., Kaitangata.
Harrison, C. F. R., Huntly.
Hazeldene, T., Denniston.
Hartley, H., Huntly.
Henderson, J., Huntly.
Hetherington, R., Huntly.
Howie, William, Walton Park.
Kelly, Peter, Kaitangata.
Leisham, G., Denniston.
Marriott, T., Huntly.
Mason, J., Springfield.
Muir, T., Huntly.
Moore, Luke Martin, Brunnerton.
McFarlane, Henry, Miranda.
McGarry, James, Brunnerton.
McGregor, Duncan, Stirling.
McIntosh, Donald, Allandale.
McVie, John, Walton Park.
O'Neil, J., Denniston.
Porter, H. R., Huntly.
Ryan, T., Huntly.
Sampson, J., Huntly.
Saunders, J., Denniston.
Shore, Joseph, Kaitangata.
Skilton, F. G., Denniston.
Skellern, R., Huntly.
Smith, J., Denniston.
Southall, James, Brunnerton.
Thomas, William, Kamo.
Troughhear, Robert, Dobson.
Turner, Henry, Kawakawa.
Vincent, James, Miranda.
Wearn, Alfred, Boatman's.
Wearn, James, Wallsend.
Williams, Llewellyn, Kawakawa.
Woods, William, Kawakawa.
Williams, F. A., Shag Point.

Second-class Mine-manager's Certificate issued after Examination under "The Coal-mines Act, 1891."

Dixon, W., jun., Kaitangata.

Engine-drivers' Service Certificates.

Issued under "The Coal-mines Act, 1891."

Archibald, W., Kaitangata.
Barlow, William John, Shag Point.
Boag, John, Shag Point.
Forrestor, Robert, Kaitangata.
Girvan, R., Kawakawa.
Greening, Luke, Springfield.
Johnstone, R. N., Kaitangata.
McVie, Gavin, Kaitangata.
Milburn, Edward, Westport.
Park, John A., Huntly.
Prentice, J., Shag Point.
Rixon, William E., Shag Point.
Todd, William, Dunedin.
Webb, Peter Oliver, Nightcaps.

Engine-drivers' Certificates issued after Examination under "The Coal-mines Act, 1891."

Cook, S., Fairfield.
Johnston, W. P., Kaitangata.
Marshall, D., Kaitangata.
Napier, A. T., Kaitangata.
Shearer, W., Huntly.

SUMMARY OF WORKS CONSTRUCTED.

The following statement shows the whole of the different classes of works constructed by the department, either by direct grants or by subsidies to local bodies, during the last twelve years (the votes for this purpose having been under the control of the Hon. the Minister of Mines), for the purpose of opening up the mineral belts throughout the colony, and also for the development of the mining industry:—

Nature of Works.	Total Cost of Construction, or Amount authorised to be expended.	Expenditure, by way of Subsidy or otherwise, by Mines Department.	Amount of Liability by Mines Department on Works in Progress.
Up to Years 1882–83 and 1883–84.	£ s. d.	£ s. d.	£ s. d.
Water-races	29,252 1 11	14,853 9 5	14,398 11 6
Roads on goldfields	21,437 11 2	13,089 16 0	8,347 15 2
Roads and tracks undertaken by County Councils, subsidised by Mines Department	52,841 17 0	21,844 16 7	10,207 15 9
Works undertaken by prospecting associations, subsidised by Mines Department	13,216 13 4	3,350 0 0	3,400 0 0
Construction of drainage- and sludge-channels, subsidised by Mines Department	5,750 0 0	2,468 15 4	781 4 8
	122,498 3 5	55,606 17 4	37,135 7 1
1884–85.			
Water-races	4,846 1 9	14,596 2 9	4,648 11 6
Roads on goldfields	13,667 10 1	9,630 9 6	12,384 15 9
Roads and tracks undertaken by County Councils, subsidised by Mines Department	13,566 14 1	6,293 16 6	12,739 17 6
Roads to mines, other than gold, subsidised by Mines Department	4,594 10 0	111 19 0	2,888 1 0
Works undertaken by prospecting associations, subsidised by Mines Department	850 0 0	108 0 0	3,692 0 0
Construction of drainage- and sludge-channels, subsidised by Mines Department	4,050 0 0	1,050 0 0	1,931 4 8
Diamond and other drills	3,600 0 0	1,858 0 0	..
	45,174 15 11	33,648 7 0	38,284 10 5
1885–86.			
Water-races	3,660 4 9	6,063 2 3	6,964 4 4
Roads on goldfields	27,543 18 8	12,360 14 9	27,567 19 8
Roads undertaken by County Councils, subsidised by Mines Department	14,773 2 3	13,043 15 9	12,477 9 2
Roads to mines, other than gold, subsidised by Mines Department	1,551 19 10	4,327 0 10	490 12 8
Works undertaken by prospecting associations, subsidised by Mines Department	11,860 18 0	1,999 5 7	6,389 5 9
Construction of drainage- and sludge-channels, subsidised by Mines Department	10,051 14 9	3,994 16 6	6,995 9 9
Schools of Mines	2,160 9 7	1,260 9 7	900 0 0
	71,602 7 10	43,049 5 3	61,785 1 4
1886–87.			
Water-races	..	1,928 14 4	3,466 0 8
Roads on goldfields	12,453 3 5	22,229 16 1	17,791 7 0
Roads and tracks undertaken by County Councils, subsidised by Mines Department	12,613 4 8	7,415 19 6	10,455 1 5
Roads to mines, other than gold, subsidised by Mines Department	..	306 1 0	110 13 1
Works undertaken by prospecting associations and companies, subsidised by Mines Department	15,671 19 6	4,521 7 3	4,618 4 7
Construction of drainage- and sludge-channels, subsidised by Mines Department	5,549 14 6	6,207 18 0	672 6 10
Diamond and other drills	422 15 6	422 15 6	..
Schools of Mines	3,183 7 1	3,383 7 1	700 0 0
	49,894 4 8	46,415 18 9	37,813 13 7
1887–88.			
Water-races	6 6 6	6 6 6	..
Roads on goldfields	6,860 4 3	17,281 11 3	7,370 0 0
Roads and tracks undertaken by County Councils, subsidised by Mines Department	2,998 15 0	8,012 5 2	3,942 4 2
Roads to mines, other than gold, subsidised by Mines Department	..	14 5 4	..
Works undertaken by prospecting associations and companies, subsidised by Mines Department	6,456 8 0	2,703 19 3	924 8 0
Construction of drainage- and sludge-channels, subsidised by Mines Department	..	1,110 4 11	2,054 10 6
Schools of Mines	1,859 3 7	2,221 19 4	337 4 3
Aids to treatment of ores	1,200 0 0	390 18 3	209 1 9
	19,380 17 4	31,741 10 0	14,837 8 8

SUMMARY OF WORKS CONSTRUCTED—*continued.*

Nature of Work.	Total Cost of Construction, or Amount authorised to be expended.	Expenditure, by way of Subsidy or otherwise, by Mines Department.	Amount of Liability by Mines Department on Works in Progress.
1888–89.	£ s. d.	£ s. d.	£ s. d.
Roads on goldfields	10,253 5 3	4,304 3 9	13,218 11 6
Roads and tracks undertaken by County Councils, subsidised by Mines Department	7,318 1 0	2,466 16 8	5,195 6 1
Works undertaken by prospecting associations and companies, subsidised by Mines Department	474 0 0	236 0 0	687 8 0
Construction of drainage- and sludge-channels, subsidised by Mines Department	..	54 10 6	..
Wharves, contributions by Mines Department	589 19 5	96 6 0	343 13 5
Aids to treatment of ores, subsidised	..	209 1 9	..
Schools of Mines	895 16 10	1,188 6 10	44 14 3
	19,531 2 6	8,555 5 6	19,489 13 3
1889–90.			
Roads on goldfields	3,834 9 7	9,148 5 9	8,005 5 4
Roads and tracks undertaken by County Councils, subsidised by Mines Department	8,507 15 8	3,451 17 11	5,928 1 3
Works undertaken by prospecting associations and companies, subsidised by Mines Department	..	..	663 0 0
Water-races	2,200 0 0	719 0 0	681 0 0
Wharves	..	150 0 0	193 13 5
Schools of Mines	1,040 0 8	1,034 0 11	50 14 0
Aids to treatment of ores	142 8 9	142 8 9	..
Tracks to open up mineral lands	1,000 0 0	207 3 6	792 16 6
Diamond drills	425 14 5	425 14 5	..
	17,150 9 1	15,278 11 3	16,314 10 6
1890–91.			
Roads on goldfields	8,811 14 4	10,815 14 8	5,201 5 0
Roads and tracks undertaken by County Councils, subsidised by Mines Department	2,703 5 0	2,252 5 5	5,027 8 4
Works undertaken by prospecting associations and companies, subsidised by Mines Department	..	..	663 0 0
Water-races	5,542 19 8	6,234 4 6	..
Wharves	..	39 9 9	..
Schools of Mines	3,847 10 0	3,898 4 0	..
Tracks to open up mineral lands	..	78 4 7	419 19 5
	20,905 9 0	23,319 2 11	11,311 12 9
1891–92.			
Roads on goldfields	14,226 5 1	8,460 0 3	11,767 9 10
Roads and tracks undertaken by County Councils, subsidised by Mines Department	3,162 0 0	1,720 18 6	4,937 10 2
Work undertaken by prospecting associations and companies, subsidised by Mines Department	1,455 5 5	336 15 9	1,663 0 0
Water-races	2,256 13 6	2,256 13 6	..
Wharves	..	..	..
Schools of Mines	1,370 19 9	1,370 19 9	..
Tracks to open up mineral lands	40 0 0	41 16 0	418 3 7
	22,511 3 9	14,187 3 9	18,786 3 7
1892–93.			
Roads on goldfields	15,199 2 4	17,325 10 0	9,628 6 10
Roads and tracks undertaken by County Councils, subsidised by Mines Department	550 0 0	1,033 0 0	4,831 9 10
Works undertaken by prospecting associations and companies, subsidised by Mines Department	970 4 9	865 4 3	1,768 0 6
Water-races	3,811 1 10	3,811 1 10	..
Wharves	..	..	..
Schools of Mines	1,232 4 4	1,232 4 4	..
Tracks to open up mineral lands	..	..	419 19 5
Artesian well-boring, Maniototo Plains	550 0 0	281 3 6	268 16 6
	22,312 13 3	24,548 3 11	16,916 3 1
1893–94.			
Roads on goldfields	18,418 19 2	15,056 0 11	13,013 18 5
Roads and tracks undertaken by County Councils, subsidised by Mines Department	5,038 11 6	2,718 17 8	5,576 10 7
Works undertaken by prospecting associations and companies, subsidised by Mines Department	2,245 19 4	1,591 10 5	1,027 7 11
Water-races	5,271 17 1	5,271 17 1	900 0 0
Drainage-channels	..	..	1,000 0 0
Wharves	..	..	..
Schools of Mines	1,555 19 9	1,555 19 9	..
Tracks to open up mineral lands	..	..	..
Repairing flood damages	500 0 0	500 0 0	..
Artesian well-boring, Maniototo Plains	800 0 0	518 16 6	..
	33,831 6 10	27,213 2 4	21,517 16 11

SUMMARY OF WORKS CONSTRUCTED—*continued.*

Nature of Work.	Total Cost of Construction, or Amount authorised to be expended.	Expenditure, by way of Subsidy or otherwise, by Mines Department.	Amount of Liability by Mines Department on Works in Progress.
SUMMARY.	£ s. d.	£ s. d.	£ s. d.
Roads on goldfields	152,706 3 4	139,702 2 11	13,013 18 5
Subsidised roads and tracks	124,073 6 2	70,254 9 8	5,576 10 7
Subsidised roads and tracks other than on goldfields ..	6,146 9 10	4,759 6 2	..
Prospecting	53,152 12 4	15,713 3 2	1,027 7 11
Water-races	56,847 7 0	55,740 12 2	900 0 0
Wharves	435 15 9	285 15 9	..
Schools of Mines	17,145 11 7	17,145 11 7	..
Drainage-channels	21,401 9 3	14,885 5 3	1,000 0 0
Diamond drills	4,448 9 11	2,706 9 11	..
Treatment of ores	1,342 8 9	742 8 9	..
Tracks to open up mineral lands	325 8 1	325 8 1	..
Artesian well-boring, Maniototo Plains	800 0 0	800 0 0	..
Repairing flood damages	500 0 0	500 0 0	..
	439,325 2 0	323,560 13 5	21,517 16 11

It will be seen from the foregoing statement that the total value of works authorised amounts to £439,325 2s., while the actual expenditure has been £323,560 13s. 5d., during the last twelve years, since votes for this class of works have been under the control of the Hon. Minister of Mines. During the past year works have been authorised to the extent of £33,831 6s. 10d., while the actual payments have amounted to £27,213 2s. 4d., and the liabilities on 31st March last were £21,517 16s. 11d.

Notwithstanding the large amount which has been expended on works in connection with developing the mining industry, a great deal more requires to be done in opening up the back country by the construction of roads and tracks; without these it is impossible for men to carry on prospecting operations systematically. There is still a large area of country comparatively unexplored between Cabbage Bay and Cape Colville, and between the latter place and Port Charles. A little gold has been found near Cabbage Bay, and the same formation, which is of a tufaceous sandstone, extends for a great distance. It is in this formation where the whole of the rich lodes in the North Island are found. It is said by some that there is not the same class of miners in the colony now, as there were in the early days, to carry on prospecting operations in the back country; but it must be remembered that in the early days of the goldfields money was far more plentiful than at the present time. The most of those who followed the goldfield in the early days were single men, having no ties to keep them in one spot other than that of good-fellowship amongst one another; with money in their pocket, and a great desire to open up a new field, prospecting was carried on with the hope that some rich find would be discovered to pay them for their labours.

In those days very few of the miners had much knowledge concerning the character of the rocks where payable lodes would likely be found, and this led to prospecting operations being carried on everywhere, without regard to locality. Indeed, it was looked on as a matter of pure chance as to what formation gold would be found in. There is no doubt if money were as plentiful now as it was in the early days, many of our young men would be equally as eager to search for fresh fields, and, with their knowledge of minerals and character of rocks where auriferous lodes are likely to exist, they probably would be more successful in making new discoveries. At the present time many of the young men have their parents to support, and, with only earning small wages, they can neither afford the means nor the time to devote to prospecting, especially to go out in the unexplored wilds, where tent, tools, and provisions must all be carried on men's backs. When the country is opened up by pack-tracks or roads it becomes an easy matter to test ground, and men can readily be got to carry on prospecting operations as the expense of getting provisions is not high.

The whole of the Hauraki Peninsula is suitable for nothing but mining. The land is not fit for agricultural purposes; nevertheless it contains riches which will support a large mining population for many years. In every place in the colony where gold-mining is the paramount industry, every encouragement should be given to get the mineral wealth developed; by so doing assistance is given to an agricultural population, to cultivate small portions of available land to supply the wants of those engaged in mining. They can realise a much higher price for their produce in the back country where mining is carried on than in the large centres of civilisation.

The west coast of the Middle Island is purely a mining locality, although there are small portions of it which are suitable for agriculture. The greater portion of it is only suitable for mining; and it is only by a large mining population being on the West Coast that any people have been induced to take up and cultivate small areas of land. Were it not for mining, it would never pay any settler to grow produce. He could never compete with the farmers in Canterbury and Otago. Those who have been engaged in mining, and who have raised their families on the West Coast, are anxious to take up small plots of land so that they can make permanent homes; by combining this with mining, they are able to earn a livelihood; and it is only by this means that the West Coast can support a large population. There are no doubt large areas of fine forest, which will in time be utilised, and afford employment to a considerable number of persons; but were the gold-mining industry to fail, many of those who are now engaged in the timber trade would have to leave and seek employment elsewhere.

The coal trade on the West Coast is gradually increasing; but the harbours are not completed to such an extent that large vessels can take away the coal to foreign markets to compete successfully with those engaged in this trade in other countries; and yet we have coal which cannot be

surpassed in the world, according to the trials made with the best coal from the Welsh mines. The experiments conducted at Woolwich show that the coal from the Westport Company's Mine at Coalbrookdale has even a greater evaporative power than the coal from the Welsh mines; and no doubt in time we shall be able to get outlet for great quantities of this coal when it can be taken away in large cargoes from our ports at a cheap rate; but at the present time the trade may be said to be confined to local consumption. At the present time about 117,444 tons per annum is imported from New South Wales, but the principal portion of this comes as back-freight by vessels carrying timber and agricultural produce from the different ports to that colony. This is felt more by the coal-mine proprietors of the North Island than in any other portion of New Zealand. The reason of this is that there are large quantities of kauri timber shipped to the Australian Colonies from Auckland, and if the vessels only get the cost of loading and unloading coal pays better than returning in ballast; and this allows a certain quantity to be imported from New South Wales at a lower cost than bituminous coal can be landed for from the West Coast to Auckland; and, with the exception of the coal from Kawakawa, Hikurangi, and Nunguru, which is semi-bituminous, none of the other coal in the Auckland District is suitable for ocean-going vessels. The brown coal from the Waikato mines, and also the coal produced in the Otago district, is only fit for local consumption. The total output from all the mines in the colony last year was 691,548 tons, as against 673,315 tons for the year previous.

Taking the whole of those dependent on gold- and coal-mining it represents a population of about eighty thousand, which shows that the mining industry is a most important one, and adds considerably to the prosperity of the colony. It is therefore deserving of support and encouragement in every way, as it is a great outlet for the employment of the working-classes. Taking the value of the produce of the gold- and coal-mines last year, it represents no less a sum than about £1,306,786.

To take the whole of the mining industry in the colony, it is gradually progressing; new discoveries are from time to time being made of auriferous quartz-lodes and alluvial workings, although the same quantity of gold cannot be got as that obtained in the shallow placer-workings in the early days. The improvements made in machinery and appliances for working the ground admit of a far larger quantity of material being operated on with less labour than formerly, and therefore make ground now pay for working which in the early days of the goldfield was passed over as valueless. The improvements made in dredging appliances enable the beds of rivers, and flats containing too large a quantity of water to work by any other means, to be made to yield up the treasures they contain, and, although dredging operations have in many instances failed in working the ocean-beaches, the time is not far distant when the difficulties now met with will be overcome, and large areas of these will yet be profitably worked, and afford employment to a large number of men. The technical education which the miners and the rising generation are receiving at the Schools of Mines have already borne fruits, and will yearly tend to have a beneficial effect on the industry, and produce a marked progress. It will also cause more attention to be given to mining and the workings of the mines on a purely commercial basis. Capital and labour must go hand-in-hand. The one is inseparable from the other in bringing mining ventures to a commercial success, and although a temporary depression may take place, fresh capital will be forthcoming to open up and develop our hidden resources. When mine proprietors become alive to their own interests and find that their properties are valueless unless they combine together, they will no doubt offer sufficient inducement to capitalists to come to their assistance.

Annexed is a statement showing the cost of works in detail which have been undertaken and constructed by the department since votes for this purpose was placed under the control of the Hon. the Minister of Mines.

I have, &c.,

HENRY A. GORDON, M.A.Inst.M.E.,
Inspecting Engineer.

LIST of WORKS on GOLDFIELDS undertaken wholly by the Mines Department, or by Subsidies to County Councils, Local Bodies, and Prospecting Associations, in Progress on the 31st March, 1894.

Locality and Nature of Works.	Total Cost, or Amount authorised.	Amount of Contribution paid by Mines Department.	Amount due by Mines Department on Works still in Progress.
NORTH ISLAND.			
ROADS (SUBSIDISED).			
Bay of Islands County.	£ s. d.	£ s. d.	£ s. d.
Road from Tuamarere Railway-station to Puhipuhi Township	482 0 0	146 0 0	95 0 0
Coromandel County.			
Mercury Bay Road	1,100 0 0	495 0 0	55 0 0
Kuaotunu–Coromandel Road	300 0 0	..	150 0 0
Pumpkin Flat–Just in Time Road	300 0 0	120 0 0	30 0 0
Just in Time Road extension	300 0 0	75 0 0	75 0 0
Mahakirau towards Mercury Bay Road	200 0 0	..	100 0 0
Bridge to Dugend's Store, and widening and metalling road from bridge to log hut	450 0 0	..	300 0 0
Lower road from Great Mercury Battery to Kapai low-level and new battery site	600 0 0	..	400 0 0
Road from junction of Red Mercury Battery up Pumpkin Flat to Waitaia	375 0 0	..	250 0 0
	3,625 0 0	690 0 0	1,360 0 0
Thames County.			
Thames–Tapu Road	100 0 0	..	50 0 0
Upper Tararu Road to Sylvia Mine	750 0 0	342 3 6	32 16 6
Te Papa Gully Road	100 0 0	..	50 0 0
Thames to Hikutaia Road	52 4 10	..	26 2 5
Road to Puriri Battery	100 0 0	5 16 6	44 3 6
Upper Tararu Road to Vulcan's workings	300 0 0	..	150 0 0
Waiomo to Puhoi Creek	200 0 0	16 10 0	83 10 0
Thames to Waikawau Road	300 0 0	18 15 0	131 5 0
Track from Tararu Creek Road to McDermott's claim	100 0 0	22 10 0	27 10 0
Track to Try Fluke Claim, Tapu	100 0 0	..	50 0 0
	2,102 4 10	405 15 0	645 7 5
Ohinemuri County.			
Bridge over Ohinemuri River at Karangahake	550 0 0	6 5 6	543 14 6
Tui Creek Track	200 0 0	64 19 3	35 0 9
Hikutaia–Paeroa Road	500 0 0	71 0 0	179 0 0
Waitekauri to Lowrie's and Birnie's	200 0 0	..	100 0 0
Paeroa–Te Aroha Road	200 0 0	..	100 0 0
Karangahake to Waihi	300 0 0	..	200 0 0
Lower Waitekauri Road	150 0 0	..	100 0 0
	2,100 0 0	142 4 9	1,257 15 3
MIDDLE ISLAND.			
ROADS (SUBSIDISED).			
Waimea County.			
Baton to Karamea	100 0 0	..	50 0 0
Marlborough County.			
Havelock Town Board.			
Havelock–Mahakipawa Road	800 0 0	200 0 0	200 0 0
Collingwood County.			
Road to Parapara gold-mining leases	600 0 0	..	300 0 0
Inangahua County.			
Globe Hill to Merrijigs	1,560 0 0	698 13 0	81 7 0
Larry's Creek to Lyell	1,080 0 0	530 17 6	9 2 6
Golden Lead to Battery	300 0 0	..	150 0 0
Cumberland Machine-site Road	400 0 0	..	200 0 0
Widening Larry's Creek Road	140 0 0	59 5 0	10 15 0
Road up Burke's Creek, Little Boatman's	300 0 0	74 10 0	75 10 0
	3,780 0 0	1,363 5 6	526 14 6
Buller County.			
Track, Fairdown, from North Terrace	150 0 0	..	100 0 0
Grey County.			
New Rush, Cape Terrace	200 0 0	..	100 0 0
Coal Creek to Seven-mile Road	750 0 0	..	375 0 0
Track, Blackball Creek, over Smoko Hill	450 0 0	..	225 0 0
	1,400 0 0	..	700 0 0
Westland County.			
New Rush, south side of Hokitika River	100 0 0	18 19 3	31 0 9
Widening Seddon's Terrace Track	150 0 0	65 10 0	9 10 0
Hillside Track, Seven-mile Creek	50 0 0	..	25 0 0
	300 0 0	84 9 3	65 10 9
Tuapeka County.			
Road to Antimony Mine	100 0 0	..	50 0 0
Lake County.			
Pembroke Flat to County Nursery	240 0 0	..	120 0 0
Skipper's Road Saddle to Deep Creek	200 0 0	..	100 0 0
	440 0 0	..	220 0 0

LIST of WORKS on GOLDFIELDS, &c.—*continued.*

Locality and Nature of Works.	Total Cost, or Amount authorised.	Amount of Contribution paid by Mines Department.	Amount due by Mines Department on Works still in Progress.
	£ s. d.	£ s. d.	£ s. d.
Southland County.			
Repairing bridges	38 13 4	13 4 0	6 2 8
WORKS CONSTRUCTED WHOLLY BY MINES DEPARTMENT.			
Dray-road, Devil's Creek to Big River	2,000 0 0	1,968 5 1	31 14 11
Road, Gannon's to Painkiller	250 0 0	..	250 0 0
Track to Diggings, Cape Foulwind	500 0 0	400 0 0	100 0 0
Extending Horse-track to Blackball Creek	500 0 0	471 19 6	28 0 6
Cedar Creek Dray-road	500 0 0	466 11 2	41 14 10
Deviation, Pleasant Creek Track	130 0 0	..	130 0 0
Wakamarina Forks to Wairau Valley	250 0 0	..	250 0 0
Road to Matarangi Goldfield	150 0 0	..	150 0 0
Tapu Creek extension	200 0 0	..	200 0 0
Track to New Find, Tairua Creek	50 0 0	..	50 0 0
Waitekauri Battery from junction Waihi Road	150 0 0	..	150 0 0
Track from Slate River to Rocky	200 0 0	..	200 0 0
Havelock–Mahakipawa Road (Pelorus Road Board) ..	100 0 0	..	100 0 0
Road up Deep Creek, Wakamarina, to Empire City Company's claim	50 0 0	..	50 0 0
Bridge over Fox's River at Brighton	100 0 0	..	100 0 0
Totara Bridge	100 0 0	..	100 0 0
Repairs to Nile Bridge	950 0 0	801 12 0	150 0 0
Cabbage Bay to Port Charles	700 0 0	360 0 0	340 0 0
Tiki to Mahikarau	250 0 0	210 0 0	40 0 0
Puriri to east side of range	500 0 0	286 18 3	213 1 9
Hampden to Horse Terrace	3,070 0 0	2,901 3 6	168 16 6
Hatter's Terrace to Haupiri	1,400 0 0	1,200 0 0	200 0 0
Grey River to Moonlight	400 0 0	380 0 0	20 0 0
Blackball Track	600 0 0	302 14 0	297 6 0
Great South Road	5,393 9 7	4,461 3 3	932 6 4
Jackson's Bay to Cascade	500 0 0	..	500 0 0
Waiau to Preservation Inlet	6,994 8 4	6,439 7 1	555 1 3
Tracks to Western Sounds	5,071 16 8	4,339 0 10	732 15 10
Tracks, Stewart Island	200 0 0	130 8 0	69 12 0
Repairs, decking, Tapu Wharf	100 0 0	10 0 0	90 0 0
Miller's Flat to Skipper's Road	580 0 0	450 0 0	130 0 0
Driving Creek to Cabbage Bay	175 0 0	..	175 0 0
Coromandel to Kuaotunu	600 0 0	170 0 0	430 0 0
Tiki to Waikawau	400 0 0	200 0 0	200 0 0
Matawai to Kaimarama	150 0 0	..	150 0 0
Thames to Hikutaia	200 0 0	..	200 0 0
Bridge over Takaka River at Pain's Ford	700 0 0	..	700 0 0
Upper Tararu Road	500 0 0	150 0 0	350 0 0
Thames to Waikawau	600 0 0	165 17 0	434 3 0
Paeroa to Te Aroha	200 0 0	..	200 0 0
Hikutaia to Paeroa	200 0 0	165 14 6	34 5 6
Karangahake Gorge to Waihi	350 0 0	..	350 0 0
Approaches, Matakitaki Bridge	250 0 0	..	250 0 0
Big River Road	1,000 0 0	162 0 0	838 0 0
Deviation Road, Larrikin's Flat	532 0 0	..	532 0 0
Bridge and approaches, Skipper's Point	1,500 0 0	..	1,500 0 0
Ahaura–Kopara Road	300 0 0	100 0 0	200 0 0
Deep Creek to Dome Creek and Long Valley, Kaituna ..	100 0 0	..	100 0 0
	39,696 14 7	26,692 14 2	13,013 18 5
SCHOOLS OF MINES.			
Schools of Mines	12,895 11 7	12,895 11 7	..
School of Mines (Otago University)	4,250 0 0	4,250 0 0	..
	17,145 11 7	17,145 11 7	..
PROSPECTING SUBSIDIES.			
Kapanga Gold-mining Company (Limited)	20,000 0 0	404 18 6	..
Ohinemuri County	100 0 0	6 0 0	94 0 0
Frying-pan Tail-race	300 0 0	161 11 3	138 8 9
Extension, Low-level Tunnel, Boatman's	150 0 0	137 7 11	12 12 1
Mr. Olderog, Arahura	27 9 0	16 4 0	11 5 0
Mr. G. Rebay, Arahura	37 10 0	33 3 9	4 6 3
Hyndman and party, Callaghan's Flat	277 14 3	258 5 0	19 9 3
Owharoa Tunnel	150 0 0	137 10 0	12 10 0
James Shaw and party	14 12 6	..	14 12 6
Charles Porter	62 10 0	43 0 0	19 10 0
Rochfort and party	62 0 0	6 13 6	55 6 6
Westland County	263 19 2	263 19 2	..
Thames County	50 0 0	20 5 0	29 15 0
Drainage-tunnel, Dunedin Flat (£1 for £1)	800 0 0	129 4 3	270 15 9
Puhipuhi Prospecting Association	100 0 0	13 15 0	86 5 0
Lakes Mapourika, Waiho, and Wataroa Miners' Association	50 0 0	20 16 0	29 4 0
Cinnabar Mining Company, Auckland (£1 for £1 10s.) ..	500 0 0	81 17 2	118 2 10
Kumara Miners' Association	11 5 0	..	11 5 0
Coromandel County (£1 for £1)	200 0 0	..	100 0 0
	23,156 19 11	1,734 10 6	1,027 7 11
WATER-RACES.			
Waimea–Kumara Water-race	22,814 18 2	22,814 18 2	900 0 0
Mount Ida Water-race	8,250 18 8	8,250 18 8	..
Contingencies	659 12 8	659 12 8	..
	31,725 9 6	31,725 9 6	900 0 0
Drainage and Tailings Channels			
Kumara Sludge-channel No. 4	1,000 0 0	..	1,000 0 0

Summary of Works.

Locality and Nature of Works.	Total Cost, or Amount authorised.	Amount of Contribution paid by Mines Department.	Amount due by Mines Department on Works still in Progress.
	£ s. d.	£ s. d.	£ s. d.
Roads (subsidised)—			
Bay of Islands County	482 0 0	146 0 0	95 0 0
Coromandel County	3,625 0 0	690 0 0	1,360 0 0
Thames County	2,102 4 10	405 15 0	645 7 5
Ohinemuri County	2,100 0 0	142 4 9	1,257 15 3
Waimea County	100 0 0	..	50 0 0
Marlborough County	800 0 0	200 0 0	200 0 0
Collingwood County	600 0 0	..	300 0 0
Inangahua County	3,780 0 0	1,363 5 6	526 14 6
Buller County	150 0 0	..	100 0 0
Grey County	1,400 0 0	..	700 0 0
Westland County	300 0 0	84 9 3	65 10 9
Tuapeka County	100 0 0	..	50 0 0
Lake County	440 0 0	..	220 0 0
Southland County	38 13 4	13 4 0	6 2 8
	16,017 18 2	3,044 18 6	5,576 10 7
Works constructed wholly by Mines Department ..	39,696 14 7	26,692 14 2	13,013 18 5
Schools of Mines	17,145 11 7	17,145 11 7	..
Prospecting subsidies	23,156 19 11	1,734 10 6	1,027 7 11
Water-races	31,725 9 6	31,725 9 6	900 0 0
Drainage and tailings channels	1,000 0 0	..	1,000 0 0
Total	128,742 13 9	80,343 4 3	21,517 16 11

LIST of WORKS on GOLDFIELDS constructed wholly by the Mines Department, or by Subsidies to County Councils, Local Bodies, and Prospecting Associations, and completed prior to the 31st March, 1894.

Locality and Nature of Works.	Total Cost.	Amount of Contribution paid by Mines Department.
NORTH ISLAND. ROADS (SUBSIDISED).		
Bay of Islands County.	£ s. d.	£ s. d.
Tiriwhanga Gorge to Galbraith's Road, Puhipuhi	237 0 0	118 10 0
Air-line Road to battery-site, Puhipuhi	73 0 0	36 10 0
Tiriwhanga Gorge to Puhipuhi	800 0 0	800 0 0
	1,110 0 0	955 0 0
Coromandel County.		
Improving road to Iona and Just in Time Companies' Mines	200 0 0	133 6 8
Making and improving track from Tokatea towards Kennedy Bay	320 0 0	213 6 8
Golden Belt Track	100 0 0	50 0 0
Tokatea Road (repairs)	300 0 0	150 0 0
Making and improving track from Golden Belt to Tiki	239 3 3	159 8 10
Making road from Ring's Bridge to Kapanga Mine	150 0 0	100 0 0
Making road to Kapanga Mine	132 0 0	88 0 0
Temporary track from Tokatea Saddle to Waikoromiko	50 0 0	33 6 8
Continuation of track from Success Company's Mine to top of main range ..	80 0 0	53 6 8
Completion of road from Tokatea Saddle to Tokatea Battery	50 0 0	33 6 8
Widening road from Matawai to Vaughan's Claim	357 0 0	238 0 0
Improving track, Mercury Bay to Waitai	100 0 0	66 13 4
Continuation and improving Waikoromiko Track	150 0 0	100 0 0
Emily Battery to Rocky Creek	60 0 0	40 0 0
Track, Bismarck Battery to Kennedy Bay	200 0 0	133 6 8
Road up Manaia	675 10 6	450 7 0
Extension of Vaughan's and Vizard's Tracks	150 0 0	100 0 0
Vizard's towards Marebel	200 0 0	133 6 8
Extending and widening Waitaia Road	100 0 0	66 13 4
Makarau to Waiau	1,600 0 0	1,066 13 4
Waikawau to Tiki	500 0 0	333 6 8
Paul's Creek to Cabbage Bay	200 0 0	133 6 8
Waikawau Creek Track	100 0 0	50 0 0
McLaughlin's Road	100 0 0	50 0 0
Manaia to McGregor's new find	100 0 0	50 0 0
Manaia to Tiki	500 0 0	250 0 0
Old saw-mill towards Matawai	200 0 0	100 0 0
Extension of Paul's Creek Track	300 0 0	150 0 0
Matarangi Track	400 0 0	200 0 0
Thames–Coromandel Road, *viâ* Manaia	300 0 0	150 0 0
Harbour View extension	210 0 0	105 0 0
Kapanga to Paul's Creek	200 0 0	100 0 0
Mercury Bay to Kuaotunu	360 0 0	180 0 0
Wainara to Kuaotunu	450 0 0	225 0 0
Sea Beach to Kuaotunu	1,650 0 0	1,450 0 0
	10,783 13 9	6,935 15 10

LIST of WORKS on GOLDFIELDS, &c.—*continued.*

Locality and Nature of Works.	Total Cost.	Amount of Contribution paid by Mines Department.
Thames County.	£ s. d.	£ s. d.
Making new road from Ohinemuri River to Karangahake Quartz-mine	650 0 0	433 6 8
Dray-road to connect Otanui Mines with crushing-battery at Maungawherawhera Creek	710 0 0	473 6 8
Improving roads from Waitekauri Road to Katikati Road	250 0 0	166 13 4
Improving road up Karaka Creek to Lucky Hit Company's Mine	263 1 0	175 7 4
Improving road to upper mines, Waitahi	258 18 10	172 12 7
Karangahake to battery	300 0 0	200 0 0
Ralph's Battery, Waitekauri	399 1 0	199 10 6
Otanui Road to mines	299 18 0	199 18 8
Road to Wick's Battery	70 0 0	46 13 4
Rocky Point Road, Tararu	300 0 0	200 0 0
Thames Borough boundary to hæmatite-mine	350 0 0	233 6 8
Widening road from bridge over Hape Creek to Otanui Mines	183 17 0	122 11 4
Track, Karangahake Goldfield	784 1 0	522 14 0
Kauaeranga Valley to Otanui	470 7 0	313 11 4
Tapu Road to mines	81 17 9	54 11 10
Tauranga Road to Karangahake Bridge-site	341 5 0	227 10 0
Karangahake Bridge	229 6 6	152 17 8
Track up Maungakerikeri Creek	93 4 4	62 2 11
Thames Borough boundary to Hape Creek No. 2	600 0 0	300 0 0
Upper Karaka Road	179 13 0	119 15 4
Repairing flood-damages, Waiotahi, Moanataiari, Karaka, and Collarbone Roads	350 0 0	175 0 0
Sea-beach to Waiomo	750 0 0	375 0 0
Te Papa Gully Road	75 0 0	37 10 0
New Find to Waiomo Battery	110 0 0	55 0 0
Rocky Point Road	429 11 10	214 15 11
Waiotahi towards Mercury Bay	522 11 0	261 5 6
Te Mata Road	178 17 6	89 8 9
Waiomo Creek to Tapu	1,499 0 0	749 10 0
Alabama Creek Track	100 0 0	50 0 0
Road from Prospectors' Mine, Puriri, to battery	50 0 0	25 0 0
Karaka Creek to Lucky Hit	365 0 0	182 10 0
Bullion Mine, Tapu, to battery	36 5 0	18 2 6
Track to Hikutaia Goldfield	147 15 2	73 17 7
	11,428 10 11	6,683 10 5
Ohinemuri County.		
Jubilee Mine Track	118 0 0	59 0 0
Track up Tui Creek	306 0 0	153 0 0
Prospecting-track, Whangamata and Waitekauri	200 0 0	166 13 4
Tramway, Karangahake to Railey's reduction-works	400 0 0	200 0 0
Strengthening bridges, Waihi Road	200 0 0	133 6 8
Paeroa to Hikutaia	400 0 0	200 0 0
Repairs, flood-damages	34 13 8	17 6 10
Hikutaia River to Maratoto Mine	180 15 0	90 7 6
Karangahake through Gorge (bridge and culverts)	200 0 0	100 0 0
Waitekauri Lower Road	360 0 0	189 2 8
Metalling Karangahake Gorge Road	170 0 0	85 0 0
Karangahake and Waihi Road	237 10 0	118 15 0
Karangahake Hill Track	87 4 0	43 12 0
	2,894 2 8	1,556 4 0
Piako County.		
Extension and completion of Te Aroha Tramway	18,000 0 0	12,000 0 0
Tramway to Fergusson's Battery, Waiorongomai	1,500 0 0	1,000 0 0
Road, Waiorongomai	497 17 0	331 18 0
Track to claims at Buck's Reef	55 5 6	36 17 0
Track, Fern Spur to Butler's Spur	231 17 9	154 11 10
Tracks up Stony Creek, Te Aroha Goldfield, &c.	54 0 0	36 0 0
	20,339 0 3	13,559 6 10
Hutt County.		
Road to connect Otorongo Bay with Albion Company's Battery, also to connect Terawhiti Quartz-mine with battery	509 16 6	210 17 0
Road, Makara Junction to Terawhiti	450 0 0	225 0 0
	959 16 6	435 17 0
SOUTH ISLAND. ROADS (SUBSIDISED).		
Marlborough County.		
Track, Deep Creek to Dead Horse Creek	68 0 0	45 6 8
Mouth of Gorge to Forks, Cullensville to Mahakipawa Diggings	450 0 0	225 0 0
Formation of road at Cullensville, Mahakipawa	217 4 0	108 12 0
	735 4 0	378 18 8
Waimea County.		
Road to open up Table Diggings	260 0 0	130 0 0
Punt over Motueka River	100 0 0	50 0 0
Repairing Baton to Table-land Track	40 0 0	20 0 0
Dove River to Baton Saddle, and from Rolling River to Wangapeka Saddle	120 0 0	60 0 0
	520 0 0	260 0 0

LIST of WORKS on GOLDFIELDS, &c.—*continued.*

Locality and Nature of Works.	Total Cost.	Amount of Contribution paid by Mines Department.
	£ s. d.	£ s. d.
Collingwood County.		
Road, West Wanganui	300 0 0	200 0 0
Bridge over Aorere River	173 14 0	115 16 0
Extending Anatoki Bridle-track	160 0 0	80 0 0
	633 14 0	395 16 0
Buller County.		
Deviation of road from Candlelight Flat to Deep Creek, Charleston	370 0 0	246 13 4
Road from Orowaiti Lagoon to North Terrace	256 18 6	171 5 8
Prospecting-track from Razorback to Paparoa Range	100 0 0	66 13 4
Track from Seatonville to Larrikin's	438 9 6	292 6 4
Waimangaroa to Denniston	787 0 0	393 10 0
Road to connect alluvial workings with Charleston Road	400 0 0	266 13 4
Track, Four-mile Creek towards Grey Valley	300 0 0	200 0 0
Road to connect alluvial diggings north of Deadman's Creek	278 0 0	185 6 8
Ngakawau to Mokihinui, *viâ* beaches	100 0 0	66 13 4
Road to connect Ngakawau Railway with Mokihinui Coal Company's workings	193 0 0	128 13 4
Lyell Bluff to Victor Emmanuel Claim	650 0 0	433 6 8
Beach, Little Wanganui to Mokihinui	300 0 0	100 0 0
Cape Foulwind Road	450 0 0	300 0 0
Road up Nile Valley	56 16 4	28 8 2
Denniston extension	850 0 0	425 0 0
Promised Land towards Motueka	380 0 0	190 0 0
Road over Gentle Annie	200 0 0	100 0 0
Extension, Lyell Creek to Low-level Tunnel	60 0 0	30 0 0
Extension of track 50 chains south of Brighton	140 0 0	70 0 0
Continuation of road, Deadman's Creek	437 17 0	218 18 6
Ngakawau Railway-station to Mokihinui	50 0 0	25 0 0
Addison's Flat towards ranges	20 0 0	10 0 0
North Terrace to Oparara Diggings	500 0 0	333 6 8
Extension of Croninville Road	100 0 0	50 0 0
Waimangaroa to sea-beach	80 0 0	40 0 0
Extension of track, Oparara to Fenian Creek	100 0 0	50 0 0
Con's Creek to Beaconsfield	80 0 0	40 0 0
Addison's Flat to Caroline Terrace	200 0 0	100 0 0
Waimangaroa to sea-beach extension	390 0 0	195 0 0
Addison's Flat to Gallagher's Lead	50 0 0	25 0 0
	8,318 1 4	4,781 15 4
Inangahua County.		
Dray-road from Soldier's Creek to Devil's Creek	647 0 0	431 6 8
Dray-road from Inangahua to Rainy Creek Battery	900 10 0	606 6 8
Dray-road from Capleston up Little Boatman's Creek	379 0 0	252 13 4
Dray-road from Capleston up Main Boatman's Creek	697 0 0	464 13 4
Dray-road from Westport Road to Inangahua River	224 5 0	149 10 0
Track from Devil's Creek to Big River	134 3 6	89 9 0
Track from Waitahu River to Capleston	358 0 0	238 13 4
Survey and expenses	250 0 0	166 13 4
Track from Caribou to Big River	728 0 0	364 0 0
Dray-road up Murray Creek to United Inglewood Claim	3,472 0 0	2,314 17 4
Road from Reefton to Big River, *viâ* Devil's Creek	614 0 0	307 0 0
Road up Big River	922 19 0	615 6 0
Continuation of dray-road up Little Boatman's Creek	169 7 6	112 18 4
Road from Capleston to Larry's Creek	640 0 0	426 13 4
Track to connect Capleston with Lone Star	75 0 0	50 0 0
Crushington to Globe Company's workings	403 0 0	201 10 0
Snowy Creek Track	85 15 0	42 17 6
Reefton to Big River	1,792 0 0	1,194 13 4
Glenroy to Horse Terrace	254 0 0	122 10 0
Devil's Creek to Globe Hill	917 6 2	458 13 1
Extension of Dray Road to Boatman's *viâ* Painkiller	53 17 6	26 18 9
Mangles Valley to McGregor's Station	600 0 0	300 0 0
	14,326 3 8	8,937 3 4
Grey County.		
Road from Notown to Deep Creek	1,100 0 0	550 0 0
Road from Langdon's to Moonlight	1,600 0 0	800 0 0
Contribution from goldfields vote towards main road	2,296 6 6	2,296 6 6
Track, Waipuna to Clarke's River	1,200 0 0	800 0 0
Track, Cameron's to Cape Terrace	700 0 0	466 13 4
Road, Limestone to Maori Creek	800 0 0	533 6 8
Red Jack's to Nelson Creek	601 17 6	401 5 0
Barrytown to Deadman's	2,240 0 0	1,493 6 8
German Gully to Arnold's Flat	120 0 0	60 0 0
Baird's Terrace to Lake Brunner	400 0 0	200 0 0
Hatter's Terrace Road	1,000 0 0	500 0 0
Irishman's to Lake Brunner	2,400 0 0	1,200 0 0
Hatter's Terrace	600 0 0	400 0 0
Track, Baird's Terrace to Irishman's	250 0 0	125 0 0
Deep Creek to Bell Hill	1,331 0 0	665 10 0
Track to Blackball Diggings	790 0 0	395 0 0
	17,429 4 0	10,886 8 2

LIST of WORKS on GOLDFIELDS, &c.—*continued.*

Locality and Nature of Works.	Total Cost.	Amount of Contribution paid by Mines Department.
	£ s. d.	£ s. d.
Westland County.		
Improving track, Butcher's Creek to Gentle Annie Terrace	225 10 0	163 13 4
Bridle-track to Kanieri Lake	719 11 0	350 5 6
Bridle-track to Eel Creek	168 9 0	84 4 6
Tunnel-track, Galway Beach to Gillespie's Beach	437 5 0	218 12 6
Road from Duffer's Creek, Greenstone Road, to fifteen-mile peg, Christchurch Road	726 9 0	480 4 6
Continuation of track, Back Creek to Eel Creek	249 4 0	166 3 4
Bridle-track, Duffer's Creek, Bowen and Okarito Road, to sea-beach	333 18 0	222 12 0
Ross Borough boundary to Mount Greenland	1,280 15 0	853 16 8
Track, Kanieri Lake to Humphrey's Gully	279 2 0	186 1 4
Track, Larrikin's to Loop-line Dam	449 11 0	299 14 0
Rough Wainihinihini to Upper Dam	450 0 0	300 0 0
Browning's Pass to Reefs	3,311 6 0	2,207 10 8
Okarito Forks to Teal Creek	600 0 0	400 0 0
Road, Christchurch to Baldhill Range reefs	500 0 0	250 0 0
Extension of Tucker's Flat Road to New Rush	170 19 6	85 9 9
Hokitika Borough boundary (Reefton) to Shotover Rush	120 0 0	60 0 0
Track to New Rush, Back Creek	100 0 0	50 0 0
Repairing old track round Wataroa Bluff	50 0 0	25 0 0
	10,171 19 6	6,412 8 1
Taieri County.		
Mullocky Gully to Silver Peak	499 15 0	333 3 4
Lake County.		
Track, Skipper's to Phœnix and Scandinavian Reefs	292 2 3	194 14 10
Track to connect scheelite-mine with Lake Wakatipu	225 0 0	150 0 0
Arrowtown to Macetown, construction	225 0 0	150 0 0
Arrowtown to Macetown, maintenance	150 0 0	100 0 0
Invincible Quartz-reef Track, Rees River	300 0 0	200 0 0
Rees Valley to company's workings	61 7 6	30 13 9
Pack-track, Criffel Diggings	50 6 6	33 11 0
Left-hand Branch Road, Skipper's	63 9 10	31 14 11
Old Morven Ferry Road	289 0 0	144 10 0
Road to workings above Cardrona	70 0 0	35 0 0
Piers, Victoria Bridge	725 0 0	362 10 0
	2,451 6 1	1,432 14 6
Tuapeka County.		
Making road from top of Terrace to Waipori Bush	300 0 0	200 0 0
Road, Beaumont to Remarkable Bush	300 0 0	200 0 0
Improving road from Waipori Township to antimony-mines, Lammerlaw Ranges	200 0 0	133 6 8
Waipori Township to Waipori Bush	200 0 0	133 6 8
Clutha River to Campbell's	76 9 0	50 19 4
Waitahuna to copper-mine	200 0 0	133 6 8
Road to open up quarry for Waitahuna Bridge	160 9 10	106 19 11
Waipori Road, *viâ* Bungtown	566 8 10	283 4 5
	2,003 7 8	1,241 3 8
Wallace County.		
Track, Colac Bay to Round Hill	200 0 0	133 6 8
Pack-track to Round Hill, Colac, and Orepuki	1,050 0 0	500 0 0
	1,250 0 0	633 6 8
Manlototo County.		
Road to Serpentine Diggings	136 10 0	91 0 0
Pig and Whistle to Clarke's Diggings	200 0 0	133 6 8
Shepherd's Hut Flat to Vinegar Hill	100 0 0	66 13 4
Kyeburn Peninsula to main road	82 0 0	41 0 0
	518 10 0	332 0 0
Fiord County.		
Dusky Sound, tracks	300 0 0	200 0 0
Waitaki County.		
Road, Naseby to Livingstone	41 12 0	20 16 0
Southland County.		
Improving tracks from Mataura to Nokomai	75 0 0	50 0 0
Improving road, Waikaka to Leatham	150 0 0	100 0 0
Improving road from Waikaka Township to Leatham Creek	30 0 0	20 0 0
Improving road from Waikaka to Waikaka railway-siding	150 0 0	100 0 0
Widening and improving bush-track to Waikawa	150 0 0	100 0 0
Waikaka to Switzer's	150 0 0	100 0 0
Road near Waikaka Township	150 0 0	100 0 0
Waikaia to Whitcombe	311 6 8	180 13 4
Waipapa to Six-mile Beach	175 0 0	87 10 0
	1,341 6 8	838 3 4

LIST of WORKS on GOLDFIELDS, &c.—*continued.*

Locality and Nature of Works.	Total Cost.	Amount of Contribution paid by Mines Department.
DIAMOND AND OTHER DRILLS.	£ s. d.	£ s. d.
Inangahua County Council (diamond)	2,000 0 0	1,000 0 0
Springfield Colliery Company (diamond)	1,250 0 0	625 0 0
Westland County Council (tiffin)	350 0 0	233 0 0
Diamond drills for prospecting purposes	848 9 11	848 9 11
	4,448 9 11	2,706 9 11
WHARVES.		
Repairs to wharf, Coromandel	300 0 0	150 0 0
Anikiwi Jetty, Marlborough	135 15 9	135 15 9
	435 15 9	285 15 9
AIDS TO PROSPECTING.		
Construction of low-level tunnel, Terawhiti	750 0 0	150 0 0
Queen of Beauty Company, prospecting deep levels	300 0 0	150 0 0
Caledonian Low-level Company, prospecting deep levels	300 0 0	150 0 0
Red Hill Gold-mining Company, prospecting deep levels	600 0 0	300 0 0
Caledonian Low-level Company, low-level tunnel	2,700 0 0	300 0 0
Lyell Creek Extended Company, low-level tunnel	300 0 0	150 0 0
New Cromwell Gold-mining Company	250 0 0	100 0 0
Deep-level Association, Waipori	450 0 0	300 0 0
Little Boatman's deep-level tunnel	600 0 0	300 0 0
Oterongia Prospecting Association	198 17 2	99 8 7
Vincent County	137 9 0	68 14 6
Tapanui Prospecting Association	25 0 0	12 10 0
Tuapeka County	12 0 0	6 0 0
Maniototo County	500 0 0	250 0 0
Pullar, Shelmerdine, and Basan	400 0 0	200 0 0
Royal Oak Association	300 0 0	150 0 0
Star of the East Quartz-mining Company	150 0 0	75 0 0
West Coast Prospecting Association	300 0 0	150 0 0
McBride and party	169 2 2	84 11 1
McLean and party	66 0 0	33 0 0
Deep-level Tunnel, Tokatea	700 0 0	350 0 0
Deep-level Tunnel, Owharoa	300 8 0	200 5 4
Deep-level Tunnel, Tapu	1,200 0 0	600 0 0
Deep-level Tunnel, Cedar Creek	1,207 10 0	603 15 0
Manuka Flat Prospecting Association	200 0 0	100 0 0
Red Hill Minerals Company	437 19 10	218 19 11
Tuapeka Prospecting Association	277 0 0	138 10 0
Cardrona Prospecting Association	800 0 0	400 0 0
Cromwell Prospecting Association	500 0 0	250 0 0
Coromandel County	550 0 0	275 0 0
Thames County	309 18 0	154 19 0
Thames Borough	200 0 0	100 0 0
Buller County	146 12 6	73 6 3
Inangahua County	488 7 0	244 3 6
Westland County	1,236 19 4	618 9 8
Grey County	871 15 2	435 17 7
Deep-level Prospecting Association, Waipori	432 9 8	216 4 10
Waipu Prospecting Association	180 0 0	90 0 0
Hokianga County	100 0 0	50 0 0
Vulcan Smelting Works, Onehunga	30 0 0	15 0 0
Ohinemuri County	100 0 0	50 0 0
Waitaki County	29 5 0	14 12 6
Waihemo County	85 9 0	42 14 6
William Fox and party	711 1 8	355 10 10
Kirk and party	176 0 10	88 4 11
Hodge and party	98 13 8	49 6 10
Carey and Hyndman	441 9 4	220 14 8
Don, Boyce, and party	107 16 0	53 18 0
Quentin McKinnon	58 10 0	29 5 0
Bullion Mine, Deep-level Tunnel	300 0 0	150 0 0
Sutherland and party	30 0 0	15 0 0
Inangahua Low-level Tunnel	6,966 0 0	3,000 0 0
Deep-level Tunnel, Manaia	451 4 0	225 12 0
Waimea Miners' Association, prospecting at Callaghan's	50 0 0	50 0 0
Totara Miners' Association, Ross	51 3 6	51 3 6
Antonio Zala	4 10 0	4 10 0
Ross, Cunningham, and another	9 0 0	9 0 0
Wm. Thompson, stores from Benmore Station	2 1 10	2 1 10
Totara Miners' Association, Ross	8 6 6	8 6 6
Harris, Davidson, and party	27 7 6	27 7 6
Boatman's Tailings Company	150 0 0	150 0 0
Boys's Tunnel, Bluespur	94 12 3	94 12 3
John Halligan and party, Ross	86 10 11	86 10 11
Totara Miners' Association, Ross, Montina and party	246 10 0	246 10 0
Gillam's Gully Prospecting Association	94 15 0	94 15 0
Deep-level Prospecting Committee, Dillmanstown	407 0 3	407 0 3
Westport Prospecting Association	25 0 0	25 0 0
Te Aroha Prospecting Association	20 12 6	20 12 6
Contingencies	484 15 10	242 7 11
	29,995 12 5	13,978 12 8

LIST of WORKS on GOLDFIELDS, &c.—*continued.*

Locality and Nature of Works.	Total Cost.			Amount of Contribution paid by Mines Department.		
WATER-RACES.	£	s.	d.	£	s.	d.
Water-main, Bull's Battery	350	0	0	100	0	0
Round Hill Water-race	200	19	0	133	19	4
Tomkiss's Water-race	100	0	0	100	0	0
Cardrona Sludge-channel	100	0	0	50	0	0
New water-mains, Thames Water-race	1,479	10	4	739	15	2
Argyle Water-race	7,653	15	1	7,653	15	1
Nelson Creek	957	16	9	957	16	9
Mikonui Water-race	14,279	16	4	14,279	16	4
	25,121	17	6	24,015	2	8
DRAINAGE- AND TAILINGS-CHANNELS.						
Drainage-channel, Lawrence (total cost, approximate)	3,000	0	0	2,000	0	0
Subsidy towards purchase of Messrs. Laidlaw and Crawford's freehold in Spotti's Creek, to allow tailings to be deposited (Tinker's Diggings)	500	0	0	400	0	0
Damage by floods, Thames	1,000	0	0	500	0	0
Sludge-channel, Smith's Gully, Bannockburn	1,000	0	0	251	1	0
Round Hill Sludge-channel survey	52	19	7	52	19	7
Compensation to J. Costello, damage done by tailings	788	0	0	788	0	0
Long Gully Sludge-channel	150	0	0	100	0	0
New Pipeclay Gully Sludge-channel	1,547	18	0	773	19	0
Kumara Sludge-channel, No. 2	2,762	17	2	2,762	17	2
Ophir Tail-race	2,300	0	0	1,150	0	0
Lawrence Drainage-channel	1,150	0	0	956	14	0
Muddy Creek Channel	2,000	0	0	1,000	0	0
St. Bathan's Channel	2,000	0	0	1,000	0	0
Tailings-outlet, Maraewhenua	1,595	4	0	1,595	4	0
Ross Sludge- and Storm-water-channel	1,554	10	6	1,554	10	6
	21,401	9	3	14,885	5	3
AID TOWARDS THE TREATMENT OF ORES.						
Testing-plant, School of Mines, Thames	1,200	0	0	600	0	0
Testing minerals, Dunedin Exhibition	142	8	9	142	8	9
	1,342	8	9	742	8	9
WORKS WHOLLY CONSTRUCTED BY MINES DEPARTMENT.						
Construction of road, Arrowtown to Macetown	9,270	6	8	9,270	6	8
Road to open up Woodstock Goldfield	1,000	0	0	1,000	0	0
Ahaura to Amuri	2,504	19	7	2,504	19	7
Waikaia Bush Road	1,000	0	0	1,000	0	0
Waitahuna Bridge	750	0	0	750	0	0
Merrivale tracks	500	0	0	500	0	0
Mokihinui to Specimen Creek	1,238	7	5	1,238	7	5
Wilberforce Quartz-reef Road	1,830	17	7	1,830	17	7
Opening Mokau River	552	8	0	552	8	0
Lyell to Mokihinui	5,098	8	6	5,098	8	6
Brighton to Seventeen-mile Beach	1,789	7	2	1,789	7	2
Whangapeka to Karamea	2,000	0	0	2,000	0	0
Hatter's Terrace to Bell Hill	500	0	0	500	0	0
Cedar Creek Road	3,000	0	0	3,000	0	0
Owen Valley Road	2,208	9	2	2,208	9	2
Cobden to Seventeen-mile Beach	3,036	1	4	3,036	1	4
Cedar Creek Road	1,500	0	0	1,500	0	0
Bridle-track to Upper Anatoki	722	8	0	722	8	0
Whangamata Road	141	10	6	141	10	6
Waikawau to Manaia	1,000	0	0	1,000	0	0
Karangahake through Gorge	1,000	0	0	1,000	0	0
Arthur's Point to Skipper's	12,167	4	1	12,167	4	1
Tracks to Coal Island	54	6	3	54	6	3
Grey Valley to Teremakau	900	0	0	900	0	0
Rimu to New Rush	829	17	9	829	17	9
Kuaotunu–Coromandel Road	500	0	0	500	0	0
Tapu to Waikawau	750	10	0	750	10	0
Puhipuhi Road	1,396	17	9	1,396	17	9
Jackson's Bay to Cascade and Gorge River district	5,310	10	11	5,310	10	11
Improving roads and tracks, Collingwood to Takaka and Motueka	10,905	8	11	10,905	8	11
Tramway from New Find to Waitekauri	100	0	0	100	0	0
Havelock–Mahakipawa Dray-road	1,311	9	0	1,311	9	0
Mokihinui to Wanganui	200	0	0	200	0	0
Burnett's Face to Coalbrookdale	200	0	0	200	0	0
Deadman's to Christmas Terrace	20	0	0	20	0	0
Low-level Alpine Claim, Lyell	80	0	0	80	0	0
Bowen Road to Salt-water Beach	60	0	0	60	0	0
Repairing damage done by floods, Westland County	100	0	0	100	0	0
Deviation of road at Kanieri Forks	140	0	0	140	0	0
Road up Dark River	200	0	0	200	0	0
Coromandel to Kuaotunu	200	0	0	200	0	0
Kuaotunu to Mercury Bay	350	0	0	350	0	0
Thames to Manaia	500	0	0	500	0	0
Cobden to Seventeen-mile Beach	400	0	0	400	0	0
Bridge over Mahinapua Creek	503	16	10	503	16	10
Garston to Nevis	1,565	17	2	1,565	17	2
Track up Waiho River	105	0	0	105	0	0
Haast Ferry to Glue-pot	126	0	0	126	0	0
Paeroa–Waihi Road	114	0	0	114	0	0
Waitekauri to New Find	250	0	0	250	0	0

List of Works on Goldfields—*continued.*

Locality and Nature of Works.	Total Cost.			Amount of Contribution paid by Mines Department.		
Works wholly constructed by Mines Department—*continued.*	£	s.	d.	£	s.	d.
Mahakipawa to Waikakaho	183	12	1	183	12	1
Oparara through gorge to gold-workings	150	0	0	150	0	0
Okira Bridge, at Dirty Mary's Creek	100	0	0	100	0	0
Lagoon Bridge	100	0	0	100	0	0
Widening Cape Terrace Road	100	0	0	100	0	0
Deviation, Granville Road	70	0	0	70	0	0
Tucker's Flat Road	247	18	7	247	18	7
Dillman's to Larrikins' Road	125	15	0	125	15	0
Track at Kanieri Lake and McIntosh Falls, Lake Mahinapua	195	4	6	195	4	6
Extension of Road, Rimu to Shallow Rush	150	0	0	150	0	0
Gillam's Gully Track	149	16	0	149	16	0
McKay's Creek, Kokatahi Track	100	0	0	100	0	0
Aorere Valley to Karamea and Mokihinui	29,938	1	2	29,938	1	2
Arrowtown to Macetown	450	0	0	450	0	0
Nelson Creek Bridge	100	0	0	100	0	0
Cascade to Barn Bay Road	411	7	0	411	7	0
Contingencies	453	11	10	453	11	10
	113,009	8	9	113,009	8	9
Roads to open up Mines other than Gold.						
Aniseed Valley to Champion Copper-mine	4,963	10	6	4,116	10	6
Richmond Hill to copper-mine	315	16	0	209	4	0
Track, Ohinemuri Coal-seam	267	3	4	133	11	8
Road, Kanieri Coalfield	600	0	0	300	0	0
	6,146	9	10	4,759	6	2
Tracks to open up Mineral Lands.						
Glory Harbour to Kopack	50	0	0	50	0	0
Port Pegasus Track	155	7	6	155	7	6
Removing snags and felling timber, Mokau River	40	0	0	40	0	0
Ngakawau Foot-bridge	80	0	7	80	0	7
	325	8	1	325	8	1
Repairing Flood Damages.						
Thames Borough	500	0	0	500	0	0
Artesian-well Boring						
Maniototo Plains	800	0	0	800	0	0

Summary of Works.

	£	s.	d.	£	s.	d.
Roads (subsidised)—						
Bay of Islands County	1,110	0	0	955	0	0
Coromandel County	10,783	13	9	6,935	15	10
Thames County	11,428	10	11	6,683	10	5
Ohinemuri County	2,894	2	8	1,556	4	0
Piako County	20,339	0	3	13,559	6	10
Hutt County	959	16	6	435	17	0
Marlborough County	735	4	0	378	18	8
Waimea County	520	0	0	260	0	0
Collingwood County	633	14	0	395	16	0
Buller County	8,318	1	4	4,781	15	4
Inangahua County	14,326	3	8	8,937	3	4
Grey County	17,429	4	0	10,886	8	2
Westland County	10,171	19	6	6,412	8	1
Taieri County	499	15	0	333	3	4
Lake County	2,451	6	1	1,432	14	6
Tuapeka County	2,003	7	8	1,241	3	8
Wallace County	1,250	0	0	633	6	8
Maniototo County	518	10	0	332	0	0
Fiord County	300	0	0	200	0	0
Waitaki County	41	12	0	20	16	0
Southland County	1,341	6	8	838	3	4
	108,055	8	0	67,209	11	2
Diamond and other drills	4,448	9	11	2,706	9	11
Wharves	435	15	9	285	15	9
Aids to prospecting	29,995	12	5	13,978	12	8
Water-races	25,121	17	6	24,015	2	8
Drainage- and sludge-channels	21,401	9	3	14,885	5	3
Aid towards treatment of ores	1,342	8	9	742	8	9
Roads wholly constructed by Mines Department	113,009	8	9	113,009	8	9
Roads to open up mines other than gold	6,146	9	10	4,759	6	2
Tracks to open up mineral lands	325	8	1	325	8	1
Repairing flood damages	500	0	0	500	0	0
Artesian-well boring, Maniototo Plains	800	0	0	800	0	0
	311,582	8	3	243,217	9	2

Henry A. Gordon, M.A.Inst.M.E.,
Inspecting Engineer.

RETURN showing the VALUE of the SALES of WATER, and EXPENDITURE on, and COLLATERAL ADVANTAGES derived from, the Working of the WATER-RACES constructed and maintained by GOVERNMENT during the Year ending 31st March, 1894.

Name of Water-race.	Value of Sales of Water and Channel-fees.	Expenditure on Maintenance.	Profit or Loss.	Cost of Construction.	Total Cost of Construction.	Percentage on Capital invested.	Average Number of Men employed.	Approximate Amount of Gold obtained.	Value of Gold obtained.	Average Weekly Earnings of Men after deducting Value of Sales of Water and Channel-fees.
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.			Oz.	£ s. d.	£ s. d.
Waimea	828 15 8	919 9 4	90 13 8	130,672 5 2		..	67	2,052	8,002 16 0	2 1 2
Kumara	5,582 4 7	1,917 8 5	3,664 16 2	40,982 16 11	193,620 0 3	8·9	116	8,348	32,557 4 0	4 9 5
Kumara Sludge-channel	..	..	..	21,964 18 2		..	..	..	..	..
Nelson Creek	..	..	..	..	90,722 10 8	..	..	..	..	..
Argyle	..	..	..	..	14,701 15 3	..	..	..	..	..
Mikonui	..	..	..	..	25,927 4 6	..	..	..	..	..
Mount Ida	1,421 19 3	1,013 8 11	408 10 4	69,607 8 9	69,607 8 9	0·6	75	2,825	11,088 2 6	2 9 4
Totals	7,832 19 6	3,840 6 8	4,164 0 2	263,227 9 0	394,578 19 5	..	258	13,225	51,648 2 6	..

HENRY A. GORDON, M.A.Inst.M.E., Inspecting Engineer.

Approximate Cost of Paper.—Preparation, not given; printing (2,350 copies), £228 17s. 3d., exclusive of plans.

By Authority: SAMUEL COSTALL, Government Printer, Wellington.—1894.

Price 3s. 6d.]