

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 dissection, 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 dissection, 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