V.—*Notes on certain Processes of Rock Formation now in Action.*

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IN the summer of 1860, my attention was directed to an interesting phenomenon occurring on the east side of Bude Haven, Cornwall. The beach is composed almost wholly of the débris of the shales, &c., which partly form the cliffs, mingled however with numerous fragments of recent sea-shells. This coarse-grained sand (of which large quantities are annually removed for agricultural purposes), is in some places becoming slowly consolidated into a sort of conglomerate, by the action upon it of the water of land-springs. Such a formation has evidently been going on at various points in the neighbourhood for many years, and, in fact, absolutely identical rocks so formed are now in their turn being worn away by the destructive agency of the sea.

I accounted for the consolidation of the sand by the natural supposition that the fresh water falling into it contained excess of carbonate of calcium held in solution by free carbonic acid, which, when it escaped by exposure to the air, allowed the carbonate of calcium to be deposited between the sandy particles as a cementing material. But I found that, in several cases at least, the water was by no means particularly hard, although, in one place where the consolidation was proceeding rapidly, I observed that the leaves of the plants growing in the interstices of the rock over which the water trickled, were quickly incrustated while living with small specks and discs of carbonate of calcium, deposited by the falling waters. These discs, by thickening and extending, soon formed a complete envelope to the leaf, and arrested further development.

A rough analysis of the consolidated sand taken from below the rock above-named, revealed to me at once that it contained

on an average 5 per cent. more carbonate of calcium than the loose sand, of which silica and alumina formed by far the larger portion. But, on the other hand, some specimens of consolidated sand from neighbouring localities actually contained less carbonate of calcium than the loose sand lying near them. These specimens were from spots where the land springs did not make any marked deposit or incrustation. One chemical difference was however noted with regard to them: they contained but a mere trace of chloride of sodium, instead of the abundant proportions found in the porous particles of the sand itself. Here, I think, lies the explanation of the result. The water of the land-springs, charged with carbonic acid, though not containing a great surplus of earthy matters, removes from the sand on which it falls, and through which it percolates, a portion of its carbonate of calcium and of its marine salts. Some of the former substance is slowly deposited from solution as a cementing material, owing to the gradual escape of carbonic acid, while the chloride of sodium and other salts, being permanently soluble, filter away almost completely. The phenomenon seems, therefore, to be generally due to a re-arrangement of some of the constituents of the sand, rather than to any addition which the fall of fresh water into it might make. This hypothesis affords a means of explaining many remarkable recent formations, and it closely resembles in its principle the theory on which I accounted for the formation and composition of the interesting mineral, Beekite (*Phil. Mag.*, Feb., 1862; *Journ. Chem. Soc.*, June, 1862). In that case it was assumed that water charged with carbonic acid and silica removed the carbonate of calcium from corals, shells, &c., and deposited silica in its room, a portion of the calcium compound also being re-arranged and reprecipitated.

Mr. S. P. Woodward, in the November number of the *Intellectual Observer* (pp. 280—284) gives an interesting note concerning the fossil human skeleton from Guadaloupe, now in the British Museum. That the fossilization of this and many other old-looking specimens may have occurred in quite modern times, is abundantly shown by the rapid rate at which deposits of travertine and similar substances, take place under the most varied conditions, and in very numerous localities. In the instance of the Guadaloupe skeleton, it would appear that the solidification of the surrounding loose coral-sand progressed gradually, forming a concretionary mass around the bones; also, that from these struc-

tures, a displacement of phosphate of calcium had occurred in the way to which I have before alluded.

The chemical conditions under which the vast geological changes continually taking place are effected, deserve more careful investigation. The study of these changes, especially so far as they concern the recent formation of rocks, must throw light on many difficult historical problems, such as those relating to the succession of life upon the earth, and to the former existence of animals and plants in strata where all traces of organic forms have been destroyed. For example:—The transposition of certain mineral compounds proper to organic structures into the rocky matrix in which such fossil structures lie, and in which these particular mineral compounds do not otherwise occur, frequently points almost with certainty, to the agency of water; this conclusion probably involving and explaining, in its turn, other local appearances.

I have mentioned the rapidity with which deposits of travertine take place in many localities, and details relating to numerous instances of this action have been recorded. Sometimes the deposit overtakes the growth of a moss, and actually arrests further increase, by enclosing the whole plant in a stony envelope. I noticed an instance near Bude, where a thick crust of carbonate of calcium had formed upon a frond of the fern, *Scolopendrium vulgare*, and had prevented the full development and ripening of its spores. In the course of ten days, this frond, which, when I first observed it, was but half covered with circular patches of the earthy deposit, had become completely coated. The circular patches were at first loosely adherent to the frond, and when removed, generally disclosed a brown discoloration of the vegetable structure beneath. Further evidence of decay was found in the presence of humous bodies, and of crenic acid in the incrustation itself. That these, and other ill-defined products of the destruction of vegetable tissues, often occur in large proportion in calcareous deposits, was strikingly shown by one specimen which I obtained from the neighbourhood of that great mass of travertine known as Southstone Rock, in the valley of the Teme, Worcestershire. This specimen was perfectly homogeneous, and contained no vegetable remains, yet when heated it blackened, and finally burnt, after the manner of peat. On analysis it was found to contain, besides carbonate of calcium, oxides of iron and manganese, and other mineral constituents, no less than 13·7 per cent. of organic

matter. This fact seems to be of some importance in connection with the origin and formation, in certain older rocks, of such fossil carbonaceous substances, as retinite, bitumen, elaterite, and petroleum.

But carbonate of calcium is not the only material which serves as a cement in consolidating sand and débris, or which constitutes a rocky deposit. In the ochre-pit on Shotover Hill, near Oxford, numerous geodes of iron-ore occur, each containing a nucleus of ochre or clay; such nodules are also found in great abundance in many other localities. The interior part of the shell of these geodes consist of magnetic oxide and of hydrated sesquioxide of iron. Exterior to this is an envelope of sand-grains, agglutinated by means of the hydrated sesquioxide. As the chalybeate water of the pit still percolates through the sand, the continuance of the consolidating process may be watched in the notable increase in size of the sandy covering of particular nodules. Again, in the same neighbourhood, in a field above Bullingdon Marsh, a formation of magnesian limestone is now going on, the deposit, in this case, covering and cementing together leaves, stems, and other vegetable fragments. The proportion of magnesium-salt in this deposit is, in some specimens at all events, sufficiently large to have induced attempts to separate it on a scale of commercial importance.

From the consideration of the various phenomena to which I have alluded, and of many others similar to them, I think we are justified in concluding that water acts as a rock-former, not only by its power of adding fresh materials, but also in virtue of its various functions as a re-arranger of the old. This view is borne out by the numerous instances where those constituents of a stratum which exist in but small proportion to its chief ingredient, gradually separate out from the mass. Illustrative examples are found in the silicified concretions about organic nuclei,* occurring in the chalk, viz.: flints, pot-stones, &c.; and also in such minerals as allophane and collyrite, rich in silica and alumina, also found in fissures of the chalk; while, on the other hand, where, as in clay, silica and alumina preponderate, there nodules rich in carbonate of calcium are found.† The septaria from the London

* The intestine movements of the decomposing organic molecules appear to have determined the action.

† The author exhibited specimens of all the minerals, &c., referred to: among them a remarkably regular calcareous nodule, from Jordan-hill N.B., and others from London clay (in the Regent's Park).

clay, with their crystallisations of sulphate of calcium, may also be here alluded to; yet the simple agency of water is scarcely sufficient to account for the large crystals of sulphate of barium, which also occur in these concretions (and in some stalactites), and for many veins of metal and insoluble metallic sulphides. However, it is possible, that in some instances, the substance found is not that first formed. If organic matter and sulphate of barium are both in contact with water, we may reasonably suppose that a portion of the barium might enter into solution as *sulphide*, and that this compound, on exposure to the atmosphere, might again recover its lost oxygen, and resume the insoluble state. An excellent example of such a conversion is found in pyritified wood, &c.; a piece of wood, saturated with protosulphate of iron soon becomes filled with innumerable crystals of insoluble sulphide of iron; and these again, on exposure to air and moisture, are reconverted into the original soluble salt.

I have preferred to give my general conclusions rather than to tabulate my numerous but somewhat discordant analyses; the Society will also, I trust, excuse the imperfection of these notes, which are intended merely to direct attention to a few connected phenomena of some interest.