NOTES ON THE ROCKS IN THE NEIGHBOURHOOD OF PLYMOUTH.

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(Read at Exeter, July, 1872.)

THE group of rocks in and around the Three Towns presents features not only peculiarly interesting in themselves, but which may be regarded, if not in all respects typical, as at least illustrative, of the geological phenomena of other portions of South Devon. We find associated within an area three or four miles in length, and about the same in breadth, a remarkable variety of strata, very dissimilar in character, but yet appearing to form portions of a fairly defined series. A few general observations upon the conditions under which they occur, and what appear to be reasonable inferences therefrom, are contained in the present paper.

Roughly what, for sake of the distinction, we may call the Plymouth group, may be said to consist of four classes of rock—slate, limestone, sandstone, and trap; the three former presenting the general characteristic of a high southerly dip, varying considerably in angle, but rarely in direction more from S. than S.S.W. or S.S.E. The general order of superposition from north to south is slate, limestone, and sandstone, which, I think, we may regard as indicating three distinct periods in the geological history of the locality. That is, we may assume that the bulk of the slate was first deposited; next, the mass of the limestone; and finally, the greater portion of the sandstone. But there is no hard and fast line between them. On the contrary, there is abundant evidence of the contemporaneous deposit of portions of each. The limestone graduates into the slate, and the sandstone is interstratified with either, in such a manner as indicates beyond controversy that the passage from one period to another was a *continuous work of time; and that whatever abrupt changes* have affected the rocks under review were due to exterior or subsequent causes. Still, this triple division suggests itself as not only convenient but correct, as signifying that the stratified rocks of Plymouth are the results of three distinct and suc-

cessive forms of operation—first, the formation of the mud banks, which are now consolidated into the older portions of the shales; second, the building of the coral reef, which constitutes in one respect the nucleus, and in another the source, of the limestone; third, the change of the nature of the detrital matter of the palæozoic river or rivers that flowed towards what is now Plymouth from an argillaceous to an arenaceous character. It being always borne in mind that these periods are united by links, resulting from the gradual—sometimes alternating—change of operation; and that the whole series has been disturbed and modified by volcanic action, manifested chiefly in a direction parallel to the line of strike.

Slate rock is the most common in the neighbourhood. It stretches from the granites of Dartmoor and Hingston Down to the northern edge of the limestone, with here and there an elvan, but without much appearance of trap until we arrive at the district under review. Near the granite the slate has generally a very small dip, averaging about ten degrees, and frequently more nearly approaching the horizontal. In the neighbourhood of Plymouth, however, from a cause hereafter to be noted, it dips at a very much higher angle. Taking different points from E. to W. north of the limestone, we find that at Cann Quarry it dips 65° S.S.W.; at Prince Rock 50° a little east of S.; at Stonehouse Bridge 60° S.; at Swilly 50° S.; at Carbeal the same; and at Trevol 70°. The average dip may be put at 60°; whilst there are places, as at Ford Hill, where it is as much as 80°; and others, as near the Devonport Workhouse, where it may be seen as low as 10°. These, however, are very local exceptions.

The bulk of the slate in the locality under notice is drab in colour, and somewhat earthy in texture. At Cann Quarry, and some other points, good blue roofing slate has been raised; and elsewhere we find it purple mixed with green. These remarks apply especially to the northern slates. On the south of the limestone the characteristics are not so distinct nor continuous; the beds are intermixed with shaly limestones, sandstones, and grits, in very irregular fashion, and, moreover, have been greatly disturbed. One very important local distinction between the northern and the southern slates is, that the latter frequently contain fossils; the former, so far as I am aware, never.

The Plymouth limestone forms a band half-a-mile in breadth, and stretching away nearly due east for several miles from its western limit at the Devonport Dockyard. Its general elevation is much lower than that of the slate hills—

averaging about a hundred feet; and whilst its summit line has been truly described as being level as a wall, its continuity is broken at several points. The Tamar, after rounding its western extremity, passes through it at Cremill; the Plym has a narrow channel at Cattedown; and at Stonehouse Pool, Millbay, and Sutton Pool, the waters of the Sound find access through the barrier to basins worn out of the slate rocks behind.

The limestone varies much in colour, structure, and dip. Its most constant features are its crystalline character, and the regularity of its divisional planes. Both on the north and south it graduates into the slate through calcareous shale. Bedding is frequently indistinct, and in some central parts of the mass apparently non-existent. It abounds in fossils—chiefly coralline in its more massive portions; whilst some of the exterior beds have yielded large quantities of bivalves and univalves; and others, with the adjoining slates, are remarkably fruitful in crinoidal remains. In texture it is generally highly crystalline, and in colour very various, ranging from black, through red, yellow, brown, and gray, to white. There is a marked increase of dip from north to south. Whilst on the northern edge the dip varies from 20° to 40°; on the southern it runs from 60° to 75°—the latter at Mount Batten. On the south, as may be seen in the fine coast section from Mount Batten to Bovisand, numerous detached beds of limestone occur, interchanged with shale and sandstone. On the north no such phenomena are apparent, although at points the limestone may be observed penetrating the slate in the manner of veins. This was to be seen recently when Catherine Street, Plymouth, was lowered.

The whole of the sandstones are found to the south of the limestone band. They are best represented at Bovisand and Cawsand, the beds continuing across the Sound (I am not here alluding to the Triassic sandstone of the latter locality), and having the same general southerly dip. They are chiefly hard, crystalline, reddish brown, and, breaking freely into rhombs, are extensively quarried under the name of "Withy Edge Stone" for pitch paving. The limestone contains numerous veins of red sandstone, filling joints and fissures; but the sandstone beds immediately to the south of the limestone are chiefly gray and drab. Purple patches, occurring at first sparsely, gradually become the predominant character of the rock. It is not very easy to trace the exact order of the sandstone series, from the irregular manner in which the strata of grit, schist, limestone, and sandstone succeed each

other, with frequent intrusions of trap, and numberless contortions. To this point I hope hereafter to be able to direct more attention. So great is the confusion, that the late Mr. J. B. Jukes was led to suggest that the sandstone might really underlie the limestone. "If," asked he, "a slate bed," which he saw there, "could have been turned back upon itself, with no more evidence than the doubling of a band of quartz, why might not the same be true of 250 yards, or 2500?"

Without presuming to dogmatize upon such a point as this, I may be permitted to say that the evidence I have at present does not seem to support such a view. In the first place, it appears to me important to consider the fact that the limestone forms a division between the non-fossiliferous and fossiliferous sections of the group; or rather, perhaps, since it is itself fossiliferous, that it indicates the recorded commencement of life in the locality. In the next place, we have evidence of the more recent origin of portions at least of the sandstone, in the sandstone veins already noticed as occurring in the limestone. Nor is this all. Beds of red sandstone were discovered with the limestone in cutting away the rock for the Victualling Yard; and in boring for the Victoria Spa, near what is now the Railway Station, three feet of red sandstone were traversed at a depth of 190 feet—almost wholly through limestone; four feet at a depth of 243 feet, and twelve feet at a depth of 353. These figures do not, of course, represent the actual thickness of the beds or veins. The average dip would reduce their real breadth or depth to certainly half these dimensions; whilst, if they fill irregular cavities, any inference of dimensions would be delusive altogether. I refer to them to show that they really afford no foundation for the hypothesis of Mr. Jukes, which at first sight their occurrence may seem to favour.

Detached from the limestone, there are no indications of sandstone northward whatever. It is, of course, a mere truism to say, that either no sandstone can have been deposited there, or that it must have subsequently been removed. The depth at which the Dartmoor granite was formed, and its intimate connection with the surrounding rocks, afford convincing proof that the district has been subjected to a vast amount of denudation; but it does not seem to be a necessary inference that the Devonian sandstones were so removed over this particular area. It may have been that, during the local sandstone period, the land to the north of the limestone, though not the limestone itself, was above water.

This is not a mere random hypothesis. It is primarily to volcanic action that we owe the present configuration of the locality. The Three Towns area appears to have been a volcanic centre, and to have been subjected first to subterranean forces, operating with the greatest effect along an east and west line from Crabtree to St. Germans, immediately in rear of the limestone. Here the effect has been chiefly upheaval. On the southern side of the limestone we find produced, however, the contortions and inversions already referred to at Mount Batten. Probably it was the same terrible agency that sketched the outline of the Sound; whilst, if the northern upheaval occurred prior to the sandstone period, it is a fair inference that to it we owe the absence of sandstone rock on the north of the line of limestone.

The trap-rock, called locally, in conjunction with some of the altered slate, dunstone, occurs in various forms. Near the surface it is generally of a dun or a reddish brown, often vesicular, and commonly ferruginous—as the result of weathering. In depth it becomes bluish gray in colour, and very hard. Occasionally it is amygdaloidal, as at Ford, where it contains crystals of carbonate of lime; and here and there fragments of slate are imbedded. Its forms of intrusion are manifold. There is hardly a hill in the immediate vicinity of the Three Towns that does not contain a trappean nucleus, or is not wholly—as those at Ford, and the Devonport Town Hall, of that rock. To its superior hardness in resisting denudation, no doubt several of these elevations owe their present contour. Sometimes it forms ridges in the direction of the axis of upheaval; elsewhere we find it in veins. Occasionally it has forced its way between the layers of the sedimentary rocks; at other points it has filled fissures previously existing. The most interesting example of its occurrence may be seen in the railway cutting above Weard Quay, not far from Saltash. Here we find a series of layers of trap interstratified with slate, more than a score in number, and varying from an inch to three feet thick. And here, therefore, the lava must have spread itself upon the sea bottom in successive sheets, with comparative quietude, and at intervals sufficiently long to allow of the deposition of considerable layers of silt between.

Taking the whole of these phenomena together, they seem to indicate the special local influence of volcanic action, operating over a lengthened period. With the exception of elvan dykes at Roborough and Cann Quarry, there is little evidence of igneous action in the slates between Dartmoor and Plymouth on the east. On the northward the trap rocks break

off about Knackersknowle; but on the west they are continued at intervals so far as Menheniot, where rises the serpentine hill of Clicker Tor.

If I might venture without presumption to deduce from these data a brief physical history of our Plymouth rocks, I should first call your attention to a time when what is now South Devon, over the whole of which similar groups are scattered, was a land-fringing sea, into which some huge river or rivers discharged vast quantities of light detrital matter; forming the mud banks now consolidated into slates. How long that process went on we cannot say; nor if there was life in that sea have we any direct local traces of its existence, until the coral animals appeared upon the scene, and commenced the formation of a reef, which probably skirted the shore at a distance for many miles, and a remnant of which now constitutes the Plymouth limestone. They toiled for ages. While they were building, the deposit of silt and the formation of shale continued, and great additions were made to the thickness of the slates. We can only guess at the cause which led to the disappearance of the reef builders. Change of level may have rendered the spot untenable by them; or the water may have become too heavily charged with solid matter; but whatever the reason, at length they passed away. Even whilst they had laboured their works had been overthrown. Storms had shattered fragments from the reef, and the action of the waters had reduced them to powder, which filled the interstices, or was thrown down around. When the restorative power ceased to be exercised, this process went on with increased vigour. Little by little the exposed portions of the reef were ground down by the slow, resistless action of the waves into calcareous mud, and a new system of deposits formed on and around its site, wherein sometimes the calcareous, sometimes the argillaceous, element predominated. For all this while the streams never ceased to yield their quota to the new formation, which now entombed the remains of the molluscs and crinoids wherewith the waters teemed. The fact that the reef was the axis of the calcareous deposits, which in relation to it would be slightly convex, appears to explain their increased dip southward, and their unconformability to the slate proper already noticed.

Hitherto water, air, and life, had been the agents at work. A new one was about to appear, and convulsive throbs heralded the advent of a volcano. For miles the strata were tilted towards the south; and, less compact than the limestone, the slate gave ready passage to the lava. But the resistance

of the limestone was limited. If not bent, it could be broken; and fissures were opened therein, that, in the course of untold ages, have been worn into the channels through which pass, or once did pass, the waters of the Tamar and the Plym. Had not these fractures been made, had the waters been set the task of forming their own courses *ab initio*, the slates would have been an easier prey, and we know that nature never wastes her strength. The gorge of the Plym at Prince Rock has a depth of 80 feet below high water mark, before the rock is reached, which there is shale. With slate rocks around, would the limestone have been thus cut, if the passage had not first been opened?

The contour of the coast was now changed, but yet the land paid tribute to the sea, though the character of the deposit was modified. The waters still brought down silt, but occasionally were charged instead with sandy matter—we may see similar alternations in streams now; and the degradation of our old friend the coral reef continued, although, perhaps, in a more casual and less systematic fashion. And so we find layers of shale, and limestone, and grit intermixing, until the arenaceous influence predominated, and the mass of the Bovisand beds were formed—fresh manifestations of volcanic power at intervals disturbing the order in which the constructive force of nature worked, and laying the foundations of the future by tracing out the Sound.

Here, for the present, at the limits of the system upon which I desired to offer these few notes, I pause. There is little evidence of the extent to which construction was exercised subsequently over the area under review. Mighty works were doubtless done, of which we have scarcely a trace. Denudation has wiped away countless ages, and brought us face to face with these old Devonian times. We have now but the skeleton of the deposits of that far distant epoch; yet that skeleton we are enabled somewhat to clothe with flesh, and, though in feeble fashion, to make the dry bones live.

Hereafter I trust I may be enabled more worthily, and with fuller detail, to return to this subject.