THE LIMESTONES OF THE PLYMOUTH DISTRICT.

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In continuation of my examination of the rocks of the south-western corner of Devon,* I now present some notes on the Limestones of the Plymouth District, including under that head both the limestones of Plymouth proper, and the detached masses of the locality, notably that at Yealmpton.

The Plymouth band is 6¼ miles in length from the Tamar at Devonport Dockyard to near West Sherford, directly east and west. Its greatest breadth, point to point, is between Prince Rock and Hooe, north to south, almost exactly a mile. Here, however, and to the eastward, continuity is broken by the waters of Cattewater, the Sound, and Hamoaze, so that for nearly a third of its length the southern margin of the band is submarine. The greatest unbroken breadth is seven-eighths of a mile; and a fair average would probably be two-thirds.

The Yealmpton limestone is about 2¼ miles in length east to west from an easterly tongue-like prolongation beyond Yealm Bridge to Kitley Creek, and has a greatest breadth north to south of five-eighths. Its line of strike is nearly a mile to the south of the Plymouth mass, of which it may still be a continuation. There are several small patches of limestone in the vicinity, which may be the remnants of larger masses once helping to fill the interval; and the compression and folding of the associated strata seem more decided near Plymouth—the same rocks occupying less space. Nor do I doubt that both the Plymouth and Yealmpton limestones, if not portions of the same reef, are associated with the same reef-system, fringing an ancient shore.

* *Vide* "The Igneous and Altered Rocks of South-West Devon," *Trans. Dev. Assoc.* xix. pp. 467–97.

The Plymouth limestone dips generally to the south, the angle increasing southwards. On the northern edge, the dip mainly varies from 20° to 40°; on the southern from 60° to 75°. But at points the beds are all but vertical; at others horizontal; and at Cattedown there is a shallow synclinal and some undulation.

Taking the average dip at 45°, and the average breadth at two-thirds of a mile, there is indicated a total thickness of 1000 yards, which is manifestly largely in excess of any probable figures. A thickness of some 2000 feet is about the most that has been claimed for coral reefs; and that the Plymouth limestone has in the main a reef origin cannot be gainsaid. The real thickness of the underlying slates immediately north of the limestone is, however, very much less than the apparent, in consequence of the repetition of beds by a series of folds—at least four in number; and as the limestone was exposed to precisely the same influences, it can hardly have escaped being acted upon in a similar way. One such fold seems to be marked by partings at Mount Batten, and south of Plymstock. The synclinal at Cattedown possibly indicates another. The manner in which thin layers of shaly limestone abut suddenly on more massive portions, as on the sea front of the Hoe, points in the same direction. In the absence of well-marked beds whose repetition can be distinctly traced, possibly this is nearly as far as we can go. It seems hardly safe yet to assume that the successive appearance southwards of ranges of massive coralline limestones at Devonport, the Hoe, Cattedown, and Oreston, indicates a quadruple fold; though it would not require much more evidence to lead me to that conclusion. Allowing farther for the secondary character of some of the existing beds (the limestones graduate into the slates through calcareous shale, and further illustrations will be given as we proceed), it may very well be that 1000 feet or less would fully represent the original thickness.

There is still less evidence of the original breadth of the ancient reef, and its associated rocks. The bends and upturned edges have been subjected to an amount of denudation impossible to definitely estimate. On the Hoe the limestone attains a height of 100 feet above the sea. At the new Laira Bridge it has been proved to form the bottom of the estuary, at a depth of 100 feet below mean tide level. In a boring for the Victoria Spa in Bath Street, Plymouth, limestone was found at a depth of 240 feet below the surface, itself very near the tide level. Allowing for dip these data would give an ascertained breadth of 450 feet at least; but it must have been much greater.

The most persistent features of the Plymouth limestone are its crystalline character, and the regularity of its divisional planes. Both north and south it graduates into the slates through calcareous shale, and detached and impersistent layers and tables of limestone intermix with the slates for some little distance beyond. So far as the mass is concerned, there is no consistency of bedding. Some layers are very thin, others range from a few inches to two or three feet; at other points again, as Professor Phillips long since pointed out, bedding is non-existent, and the rock consists of irregular coral masses. One block recently dislodged in the Radford quarries measured 60 feet by 30 feet by 25 feet, weighing some 3000 tons. Some of the beds near the northern margin are affected, like the adjacent slates, by cleavage.

The colour ranges from black through red, yellow, brown, dove, chocolate, green, bluish-green, and grey, to white—alike in mass, and more commonly, so far as the positive tints are concerned, in variegation. The black excepted, nearly all these hues are due to the admixture of iron in one form or another; and that the presence of this metal even thus finely disseminated makes a great difference in the hardness of the rock, may be noted from the ridges formed by the iron-coloured veins in the slabs of paving stone in Plymouth streets. The fossiliferous portions are also slightly harder, and their proportion of calcite is slightly less than that of the body of the rock in which they lie. Hence the relief given them in weathering.

Enough has been said to show that the Plymouth limestones are very far from pure. Here and there in the more crystalline and uncoloured portions there is a tolerably close approximation to purity; but even the definitely crystalline forms of the calcite have, as a rule, some admixture. Professor Prestwich has collected analyses of various typical limestones, which show a varying content of carbonate of lime as follows: Chalk, 98·40; Chilmark Portland, 79; Kimmeridge, 75·7; Bath Oolite, 94·59; Bolsover dolomite, 51·2 (carbonate of magnesia, 40·2); Solenhofen, 96·24; Geneva Jurassic, 91·52; Devonian marble, 94; Devonian dolomite, 57·8 (carbonate of magnesia, 39·7); Silurian, 44·6 (silica, 52·4).* The Plymouth limestones are, as a rule, far less pure than the Devonian examples here cited, containing at times, in addition to the

* *Geology*, i. 29, 30.

chief constituent—carbonate of magnesia, silica, peroxide, protoxide, and sulphide of iron, argillaceous matter, manganese, carbon, and occasionally lead, some one or other being generally present, singly or combined.

It is, however, impossible, short of a series of analyses, to deal fully with the constituents of the local limestones, since they vary too much to be put more definitely in general terms. Apart from the dolomitic varieties, which themselves vary, and excluding the extremes on either side, the average percentage of non-calciferous matter may be put at from 10 to 30 per cent. Some idea of its aggregate extent will be gathered from the large quantities of clay, of sand, and of ochreous deposit, left behind in the caves and fissures by the waters which have removed the soluble carbonate, to carry it onward, or to redeposit it in the form of stalactite and stalagmite.

For the purposes of this paper I have made an examination of some of the more characteristic varieties of the Plymouth limestones, macroscopically and microscopically. Sections have been cut for the microscope; and I have also examined microscopically the insoluble residues left after removing the carbonate of lime by hydrochloric acid; while Mr. Billing, F.C.S., of Messrs. Burnard, Lack, and Alger, has kindly made some chemical analyses. My chief investigation has, however, been physical, with the main object of ascertaining the leading structural characters of the various specimens, and if possible of arriving at some conclusions as to their origin.

It will be borne in mind that limestones may be formed in three ways. They may be organic—the result of the secretion of carbonate of lime from the water by coral polyps, foraminifera,* molluscs, or other organisms. They may be chemical—deposited from solution.† They may be mechanical—the result of the wearing down and redeposition of previously-existing or currently-forming rocks of either

* The minuter forms of pelagic life are estimated by Dr. Murray to represent in a square mile of sea water, 100 fathoms deep, no less than 16 tons of carbonate of lime, which as they die falls to the bottom. Dana has estimated the growth of a coral reef at a sixteenth of an inch a year.

† The quantity of lime which in one unnoted form or another sea water may contain is considerable. In the first place, salt water has a strong solvent power over carbonate of lime, varying with the form of the substance operated upon, and with other conditions. Experiments have shown a variation in grammes per litre between 0·395 and 0·032. The range is a wide one, but for the present purpose the rate is less important than the fact, and its corollary of deposition.

type. And again, all three causes may be in contemporaneous operation to create or to modify.

The results of my examination may be given as follows:

1. Grey limestone, Cattedown.

Much of the grey Cattedown limestone is highly fossiliferous, and yields beautiful specimens of weathered corals, to be seen on old faces in the quarries, and on old walls; it is, in fact, largely, if not essentially, a reef limestone. The specimen cut did not, however, present any visible organic trace where sliced. It was light grey in colour, highly crystalline, and even-textured.

Under the microscope it was found to contain a small fragment of coral enclosed in the general mass. The ground of the section was mainly granular, with a few well-cleaved calcite crystals. There were some more transparent granular veins, and several calcite patches of irregular outline showing good cleavage lines. An irregular ferruginous fringe enclosed the coral fragment, for the most part following its outline, and indicating also some small rectangular sections. The coral fragment seems in some fashion to have played the part of nucleus—to have had deposited upon it a ferruginous film in association with a growth of small needles of calcite, and to have been enclosed in a mass of coral sand or similar reef *débris*, which has lost all organic traces, but still gives evidence of clastic characters.

2. Red limestone from Radford.

This was a full-red, highly crystalline rock, to all appearance almost wholly composed of red calcite. There were grey veins and patches, but these were excluded, and the portions sliced and otherwise examined were the pure red.

Chemical tests showed that, as was to be anticipated, the colouring matter was peroxide of iron.

The microscope showed that the matrix consisted essentially of calcite in granular and in crystalline forms, clouded, and with some well-marked cleavages. It was, in the main, a rock of secondary type—a deposit from lime held in solution. Minute specks of ferrite abounded, with a few crystalline forms indicating hematite.

The insoluble residue left after treatment with hydrochloric acid was much larger in quantity than had been anticipated, and showed that the colouring matter was not present alone. Under the microscope it was seen that in addition to some very fine grains of silica there were groups of sponge spicules.

3. Yellow limestone from Radford.

Save for the difference in colour the microscopic description given of the red variety will apply to this also; and here too the colouring matter was peroxide of iron.

Under the microscope much the same results were obtained as with the red. The crystalline characters were prominent, with some good cleavage areas. The ferruginous feature was strongly marked, and the section generally had a dirty look.

4. Black limestone, Pomphlett.

A hard, compact, black, crystalline limestone with white veins, showing no visible traces of organisms to the naked eye—had evidently undergone considerable change.

Chemical analysis revealed the presence of sulphide of iron. No point of note was developed by etching the surface whence the microscopic section was cut.

Under the microscope the general texture was seen to be between granular and mottled. Some fairly-defined and cleaved crystalline patches of calcite were thickly charged with black dusty matter, which elsewhere appeared in minute ovoid particles, nuclei, and strings. The calcite in the veins had a semi-radiated structure.

Some white spots, surrounded by dark rings, appeared to indicate the presence of foraminiferal or allied organisms, and on careful search other traces were found, though all were more or less obscure. A few minute crystals of iron pyrites were also visible.

The insoluble residue from the portion of rock treated with hydrochloric acid, consisted wholly of very minute particles of carbonaceous matter, which on washing deposited very slowly. A slight greasiness was also indicated. Under the microscope these particles gave no indication whatever of structure. They were the minutest form of organic *débris*.

Some dark-grey Plymouth limestones are thickly charged with fragments of broken organisms; but differ from this in their much smaller content of carbon. In them the organic matter is chiefly the remains of corals, encrinites, molluscs, and the like; but the Pomphlett bed must have been largely made up of the decayed remains of algæ, or of the softer parts of animals—the former apparently predominating.

5. Green limestone, Yealmpton.

This is a remarkably beautiful variety, chiefly banded in shades of green, but at times giving a bluish tinge, and occasionally bearing deep chocolate patches. It has generally a massive translucent aspect.

Chemical analysis proved the colouring matter here also to be iron, and it subsequently appeared to be glauconite.

The section showed a granular ground, with a somewhat flowing texture here and there, but with less distinctly-structured calcite than in either of the other varieties. The colouring matter was disseminated in dots, strings, and opaque patches, and there was no indication in any of these of crystalline outline. All was amorphous, indicating, as already mentioned, glauconite.

The solid residue amounted in the portion tested to quite twenty-five per cent. It was very flocculent in solution at first, but afterwards deposited most quickly as an earthy greenish mass, which presented no noteworthy features under the microscope, except that the greenish specks of colouring matter could be distinctly made out. The importance of the identification of glauconite here will be seen hereafter.

6. George Lane, Plymouth.

One of the most interesting varieties of the Plymouth limestone is supplied by tabular masses found in stiff clay in George Street. The division line between the slates and the limestone is a little to the south of George Street, but here, as elsewhere in the area, there are patches and bands of limestone intercalated among the slates. The point where the tabular masses were found, is at the extreme eastern end of what was once the inner reach of Millbay, less than 10 feet above the modern high-tide level. Loose shillet-rock was found to be overlaid by tough yellow clay, in which the limestone slabs were embedded, mostly on edge, as if the only change that had taken place since the strata of which they formed part were tilted, had been the clayey re-conversion of the loose shaly stuff among which they were interspersed. The noticeable feature in this limestone was that its upper surface had been so corroded (in part) as to reveal a number of organisms, chiefly coralline, in bold relief, to the extent at points of half an inch. The under-surface of the slabs presented no such appearance, nor did the body of the stone—a dark-grey crystalline rock—show visible organic traces. The suggestion was that these tables formed part of a thin surface on which the corals, &c., had grown. It will be borne in mind that they represent the first definite appearance of calcareous matter in the Plymouth old Devonian sea, and lie at the very base of the limestone system.

The microscopic section had a banded appearance to the naked eye, which somewhat recalled that of a section of volcanic ash from Highweek, alike in its brown, dusky hues and in its texture. The microscope did not reveal any special details. The linear structure was emphasized, but some points appeared fogged, and the crystals of calcite visible were as a rule muddled and obscured. A granular texture was, however, indicated in the darker bands, between which the calcite chiefly lay, with lines and specks suggesting microliths in cross and longitudinal section.

When the surface from which the section had been cut was etched by hydrochloric acid some additional traces of organisms were revealed, but none of importance.

The carbonate of lime was then extracted from a fragment by means of hydrochloric acid; and it was found that the insoluble residue was equal to quite sixty per cent., and that for the most part it held together in loose-textured, ashy-looking layers, corresponding to the dark bands of the section.

Under the microscope this residue resolved itself mainly into saccharoid aggregates of clear siliceous granules, which gave no definite crystalline forms, and associated with which in parts were groups of sponge spicules, the apparent microliths. Many of the grains were partially invested with a dark coating of metallic lustre, readily identified as iron-peroxide, and the presence of which accounted both for the ashy hue of the rock and the muddled appearance of the section.

The characters which suggested a volcanic origin for the basis of this rock did not therefore hold on closer examination; but I cannot help thinking that we may have here in part the results of the degradation of a tuff. Contemporary tuffs occur at no great distance, and there is tufaceous matter in some of the adjacent slates. The absence of any distinctly recognizable volcanic mineral is no valid argument against such an hypothesis, for such are rare in the local tuffs. The real difficulty lies in the fact that the tuffs are mainly composed of broken felspar crystals. Their quartz associates may, however, have here been of a more stable character, or variation in size may have led to a certain assortment. Again, some of the siliceous matter may have been organic. In any case this material formed the basis on which the sponges and corals grew, which afterwards developed in the great limestone reef.

7. Hard Head from the Hoe.

"Hard head" is the name given by the quarrymen to an impure limestone of varying thickness, chiefly a pinkish grey, which overlies the ordinary limestone at certain points. It has a rough feel, is finely granular, at times saccharoid in aspect, and occasionally encloses fragments of the common limestone. It is not burnt for lime, but is used as a rough building stone and for road metal. Visible fossils are very rare. The more arenaceous portions of this rock weather rough, the sand grains either standing out, or leaving depressions where they have fallen away. They may often be wiped off with the finger.

On treatment with hydrochloric acid this rock gives considerable insoluble residue, apparently the same in character in various examples, but differing in the proportion of its constituents. A good deal of the matter is very fine, and remains for some time in flocculent suspension. The colouring matter, when present, is peroxide of iron. This residue consists of fine grains of siliceous sand, which I have noted up to twenty-five per cent, fine clayey matter, and fragments of siliceous organisms. On an average it varies between twenty and thirty per cent.

A deep and narrow fissure in the "hard head" recently exposed at the West Hoe was filled with sandy matter, which was used for building purposes. This on examination I found to be wholly derived from the decomposition of the "hard head," being a naturally-formed insoluble residue, mixed with small fragments of the original rock and calcite.

Under the microscope the residue from the "hard head" was found to be chiefly made up of broken quartz grains and aggregates of sponge spicules, with a few grains apparently of felspar, and a very small proportion of blackish granules, which might be a pyroxenic mineral. Neither here nor in any other example did I find such quartz crystals as are reported by Mr. Wethered, F.G.S., from the Carboniferous limestone of Bristol, but I cannot venture to say that none exist. A fine argillaceous matter may have been the result of felspar disintegration.

A considerable quantity of the sand from the fissure was examined for its larger constituents under a hand lens, but only small portions of the parent rock, with fragments of calcite, and quartzose and felspathic materials, could be detected. The finer washings were then examined under the microscope, after the calciferous portions had been removed by acid. The result was practically the same, so far as the arenaceous matters were concerned, but there were included also some spicular aggregates. Except that they were more definitely coloured, the grains had the same aspect as those in No. 8; but further treatment, extracting all that could be removed of the ferruginous matter, left the grains much clearer. A few organic fragments beside the spicules were also seen.

The idea was suggested, on the examination of this and the next variety, that there had once been present something of an oolitic aspect, but that it had been destroyed by the causes which have given these limestones generally their crystalline character.

8. Red calcareous sandstone, Drake's Island.

Sand is mixed with the limestone in various proportions at different points; but the most characteristic example I have found is a deep-red, very fine-grained, and compact variety, which occurs on the beach at Drake's Island, and which is possibly the remnant of a vein, rather than a bed.

The microscopic section shows that the body of the rock is stained through with ferrite, and that the quartz grains, which give good colour reactions, are fairly rounded and regular in size—the structure being distinctly granular, but with an occasional linear association, and some calcedonic veins.

Treated with hydrochloric acid, this rock lost rather more than half its bulk, and the iron colouring matter was set free in the form of an impalpable bright red powder. The siliceous matter was loosely associated in groups and lines, forming what approached to a linear network, but generally had the appearance of saccharoid aggregates. Some granules were clear, but the majority were partially invested with minute particles of red peroxide of iron. Placed side by side, no distinction could be made out between these and the granules in the George Lane variety, beyond the fact that the partial metallic investment of the latter was black, instead of red.

The aspect of the fragments of this rock after the lime had been dissolved out has suggested a possible origin for the dark-red schistose rock at Radford, referred to by me last year as "very light and open textured," and as seeming to have been "originally an aggregate of volcanic sand, largely mixed with an iron oxide," which had "parted with some of its constituents, possibly through the action of water."* Remove the carbonate of lime from the Drake's Island sandstone, and the resulting rock would hardly be distinguishable from the Radford, even to the chalcedonic veins.

I shall best be able to lead up to the conclusions which I think may be drawn from the facts set forth, if I give a general outline of the manner in which modern limestones are now being formed in the Pacific, as illustrated by Dr. Guppy; with a supplementary note from the Red Sea, by Mr. Barker. These show, as it seems to me, a very remarkable parallelism between the processes of modern seas and those of our Devonian ocean, and will help us to understand the really diverse origin of different parts of what we have been accustomed to call and group under one head as the Plymouth limestone.

Dr. Guppy thus classifies the recent calcareous rocks of the Solomon Islands:†

1. "Coral limestones, properly so called, which are mainly composed of the massive corals in different stages of fossilization."

2. "Coral limestones, which have the composition of the *coral muds and sands* that were found by the '*Challenger* Expedition' to be at present forming near coral islands, and along shores fringed by coral reefs. They are derived chiefly from the disintegration of the neighbouring reefs; but they receive large additions from the shells and skeletons of pelagic organisms, as well as from those of animals living at the bottom."

To this group he assigns three divisions. (*a*) A compact, but at times crystalline limestone, with now and then a fragmental structure—chiefly crystallised carbonate of lime, with animal or algal remains, corals taking only a secondary part. (*b*) Chalky coral limestones, chiefly composed of organic remains. (*c*) Compact, often crystalline, limestones

* "The Igneous and Altered Rocks of South-West Devon," *Trans. Devon. Assoc.* xix. 470.

† *The Solomon Islands: Their Geology, &c.*, pp. 73–80. I have to express my obligations to Dr. Guppy not only for kindly replying to questions, but for favouring me with examples of some of the rocks described by him.

of homogeneous texture, "apparently formed by the consolidation of the calcareous ooze found at the bottom of the lagoons and lagoon-channels inside coral reefs. A and B contain ninety to ninety-five per cent. of carbonate of lime, the residue being made up of common volcanic minerals, argillaceous matter, and a small proportion of siliceous organisms. In one specimen of B there was a considerable amount of magnesia.

3. A third group is "largely composed of the *débris* of volcanic rocks mixed with the shells of foraminifera, molluscs, and of many other calcareous organisms"—volcanic muds and pteropod oozes; and a hard limestone—"containing usually about sixty per cent. of carbonate of lime, the remainder being volcanic *débris*—the kind of deposits we find forming at the present time on parts of the coast where the growth of coral reefs has been to a great extent repressed by the sediment brought down by the streams."

The pteropod ooze rocks are described as very friable, greenish-grey in colour, and as containing among other matters a great number of glauconite-like casts of the foraminifera.

4. Foraminiferal limestones, hard and compact, containing usually from seventy to eighty per cent. of carbonate of lime, the residue consisting of the volcanic minerals . . . and glassy fragments, together with a large amount (five to ten per cent.) of reddish siliceous casts of foraminifera, and a quantity of argillaceous material.

Of these there are two forms—one composed of the tests of both pelagic and bottom forms of foraminifera; and the other composed chiefly of the tests of pelagic foraminifera, and having the composition of the globigerina ooze.

5. A rock resembling a deep-sea clay, with 20·79 per cent. of carbonate of lime, the depth being probably not less than 2000 fathoms.

Mr. D. W. Barker, writing to *Nature* from Massowah, describes the sea bottom on the inside edges of the coral reef there as consisting of a greyish sand, chiefly a mixture of disintegrated coral and fine drift alluvial sand blown over from the mainland, while the bottom of the harbour was composed of nearly black mud.

With these hints we can have, I think, very little doubt in recognizing in the Plymouth limestones:—

A. Coral limestone answering to Dr. Guppy's No. 1.

B. Coral limestones corresponding to his No. 2, in which the form of the original coral sand seems to be partly preserved in the granular structure—both his *a* and *b* varieties being represented.

C. In the Yealmpton green limestone a rock of partially analogous character to the pteropod ooze variety, and one which was evidently formed at a considerable depth, since we have no reason to believe other than that the glauconite it contains represents the organic matter of the foraminiferal shells of the ancient seas, precisely as the modern glauconite.

D. I am not aware that until now the existence of foraminifera has been recognized in our local limestones (*vide* the Pomphlett), and apart from the glauconite the traces are no doubt obscure; but allowing for the changes in the texture of the Devonian limestones Dr. Guppy's No. 4 may very well be represented.

E. There seems to be evidence that some of our limestones are associated with volcanic muds or tuffs or their *débris*, though the point is by no means prominent. Not only are beds of lava, ashes, and tuffs, interstratified with the slates which form the bulk of the rocks underlying the Plymouth limestone, but there are points where volcanic material occurs close to the base of the limestones, and microscopic examination also has detected fragments of scoriæ and lapilli in what have appeared to be ordinary clay-slates.

F. That some of the arenaceous bands of the limestones may have originated in the way described by Mr. Barker, by the admixture of blown sand with coral mud, but that the clastic silica is as likely to have been detrital as æolian, while some of the siliceous constituents of these rocks, beside the identifiable spicules, are no doubt derived from siliceous organisms.

G. That the black marbles originated in a deposit of calcareous mud thickly charged with animal matter, not improbably akin to the black mud of the harbour of Massowah.

H. That the Plymouth limestones, therefore, represent practically the results of the leading processes of marine limestone formation recognized at the present day, and particularly as set forth by Dr. Guppy—partially indicating considerable depths, but in the main a comparatively shallow sea, and a fringing reef at no great distance from the land. All this is quite in harmony, so far as the Plymouth limestones are concerned, with the views expressed by Dr. Murray, and it will be borne in mind that I am not dealing with those of any other locality.

In conclusion, I have to express my hearty thanks to M. Dupont, director of the Royal Museum of Natural History at Brussels, who has very kindly sent me the results of his investigations of the Devonian limestones of Belgium. Dividing these rocks into two series—the coralline limestones proper, and the limestones formed in the main of coral detritus—the one massive, and the other stratified—and accepting the hypothesis of Dr. Murray, M. Dupont has demonstrated in the most brilliant manner the existence in Belgium of Devonian atolls, as at Roly, Philippeville, Beaumont, Renlies, Rance, Nettines, and elsewhere, and of magnificent examples of fringing reefs in the Ardennes. "Il en ressortira," he concludes, "avec une évidence aussi complète, la conclusion que les diverses manifestations de l'activité vitale des organismes constructeurs de rècifs ont persisté avec identité à travers les temps gèologiques dès la pèriode primaire, et qu'il est indispensable d'appliquer aux amas de calcaires construits des règles et méthodes stratigraphiques spéciales, bien distinctes de celles que réclame la stratigraphie des roches sédimentaires."

It will be seen that the results of my examination of the Plymouth limestones lead directly to the same conclusions. M. Dupont found it impossible to explain the phenomena of some of the Belgian limestones, on the ordinary methods of stratigraphical geology; but his difficulties were removed when he recognised that these limestones were either formed by corals or their *débris*, and followed up the line of enquiry thus indicated. The solution of the anomalies recognised in some of our limestones is probably to be found in the same direction. Certainly there is no difficulty in applying these principles to the limestones of Plymouth, which when interrogated in the same manner speak as plainly as those of Belgium.