THE DEVONIAN LIMESTONES OF LUMMATON HILL, NEAR TORQUAY.

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I. Introduction.

THE quarries on Lummaton Hill, two miles north of Torquay, are well known to all who are interested in the Devonian limestones, and have yielded a larger number of fossils to collectors than any other quarries near Torquay. But although geologists have visited these quarries for the last 50 years or more the earliest description of them which I can find is that written by the Rev. G. F. Whidborne for Davidson's Monograph on British Brachiopoda in 1882.*

Referring to the three contiguous quarries on the eastern side he says, "They are in a mass of dense, crystalline, bluish-grey limestone, with occasional joints, and with hardly any signs of bedding. Fossils occur rarely scattered through them, but are very difficult to extract entire. Occasionally, however, there are local accumulations of corals and sponge-like growths, and at one spot on the top of the third quarry is a small exposure of the rock where the smaller fossils occur in great numbers, and may in many cases be easily detached from the matrix. It is most probable that from this spot most of the so-called Barton fossils were obtained. At the base of the quarry, almost perpendicularly below this, similar fossils occur in numbers, and this would lead to the supposition that the dip is here a great one."

Mr. Whidborne informs me that by "sponge-like growths" he meant Stromatoporoids, but his account gives the impression that only one kind of limestone is to be seen, and that fossils occur in local accumulations. His inference with regard to the dip, however, I believe to be correct.

In his own Monograph on the Devonian Fauna he again refers to the spot from which he obtained so many fossils, and writes: "Most of the Crustacea at Lummaton have occurred in the bed at the top of the quarry, which is apparently little else than a shell-heap and which was probably a local and littoral deposit. This would explain the fact that the Trilobites are almost always found there in a fragmentary condition; for most likely they had decayed and fallen asunder before they reached their place of deposition."†

Mr. Whidborne's observations certainly seem to show that there is a bed or band which is specially rich in small shells,

* Supplement to the *Devonian Brachiopoda*, *Pal. Soc.* for 1882, p. 6.

† *Pal. Soc.* for 1888. *Devonian Fauna*, p. 2.

Trilobites and other organisms, but that this is in any sense a littoral deposit I very much doubt. In a subsequent passage, however, he expresses himself in terms with which I can fully agree, thus (p. 180): "Judging from the general facies of the Lummaton fauna it did not inhabit deep water, and was exposed to the action of strong currents and tides." Such conditions would suffice to account for the fragmentary state of the Trilobites.

Mr. Ussher made a few remarks on Lummaton in his paper on "The Devonian Rocks of South Devon,"* observing that "from its massive nature the structure of the Lummaton limestone, as also that of Barton, which I correlate with it, is not apparent. The Brachiopod fauna is in a very restricted space and the rock is there very similar to parts of the Ugbrook Park and other limestone masses on the border-land between the middle and upper Devonian." He also notes that Dr. Kayser correlates the Lummaton shelly limestone with the upper part of the middle Devonian.

In his use of the word "structure" in the passage above quoted I understand Mr. Ussher to mean tectonic structure, and that he was unable to recognise any definite dip or any succession of beds either in these quarries or in those of Barton.

In his later Memoir on the "Geology of Torquay,"† Mr. Ussher describes the Lummaton limestone in the following terms: "The Lummaton limestone is bounded by the New Red rocks on the north and west. It is well exposed in the quarries on Lummaton Hill, and consists for the most part of a pale grey or dove-coloured finely-crystalline, massive, coralline limestone in which *Smithia hennahi* is conspicuous. The rock appears to be partly dolomitic in the western quarries. In the large eastern quarry rubbly, broken, shelly limestone occurs in one or two places, extending from the surface at the top of the quarry irregularly downward for a few feet in the more massive rock."

This description does not apply to the southern part of the eastern quarry, and species of *Smithia*, so far as my own experience goes, have only been found in the western part of the north-western quarry. Lastly, recent excavations have shown that shelly limestone occurs at the bottom of the northern quarry as well as at the top, confirming the statement made by Mr. Whidborne in 1882, and also proving that certain Brachiopods are abundant in both the northern quarries.

The above are all the special references to Lummaton Hill that I have been able to find, and from them I think it would be inferred that there was little worth seeing on Lummaton Hill beyond a massive limestone composed chiefly of corals, but including some patches or beds of shelly limestone, the relations of which to the main mass were somewhat obscure. I propose to

* *Quart. Journ. Geol. Soc.*, vol. xlv, p. 503.

† *Mem. Geol. Survey. Explanation of Sheet 350*, p. 65, (1903).

show that at least three different limestones enter into the composition of the hill and that each of these presents features of special interest.

In the first place and before describing these limestones let me express my appreciation of the excellent work done by my friend Mr. Ussher. This part of South Devon is one of the most complicated and broken-up portions of the British Isles, and when Mr. Ussher commenced his labours the very succession of the rocks in it was quite uncertain, and it took many years of careful observation and mapping, and a survey of the whole Devonian area east and south of Dartmoor, before he could establish the actual succession of the great series of beds. With regard to the Middle Devonian, he was able to show that the limestone series is divisible into a lower stage (partly Eifelian, partly Givétian) and an upper stage which is supposed to be partly of Middle (Givétian) and partly of Upper Devonian age. He states that the lower beds are generally darker in colour and more distinctly bedded, and that crinoidal limestones are common in them; while the upper series consists mainly of massive limestones generally of a pale colour and without any distinct bedding.

Thus Mr. Ussher's work, while greatly advancing our knowledge of this limestone series, leaves it without any well-defined middle portion. No one who knows the country round Torquay will be surprised at this, for the district is so flexured and faulted that the limestones form a number of small isolated patches, and it is very difficult to make out any sequence in them for more than a short distance, or to collect a sufficient number of fossils for palæontological comparison. Large portions indeed contain few fossils except *Stromatoporoids* and scattered corals.

Lummaton Hill is part of one of these isolated limestone masses, but one in which exposures are numerous, and it so happens that two of the quarries have been worked during this year (1905), thus exposing fresh faces of limestone to observation; while the southern quarry has remained unworked, and the structure of that portion of the limestone is beautifully shown on its partly weathered surfaces.

2. Evidence of Succession.

I will first briefly state my reasons for thinking that a definite and nearly continuous succession can be made out in this limestone-mass, and will afterwards describe the quarry-sections in detail.

The starting-point, or basis, of the stratigraphical evidence is Trumland's quarry on the Teignmouth Road, a little south-east of Lummaton Hill. This quarry is mentioned by Mr. Ussher as

GEOLOGICAL MAP OF THE LUMMATON AND BARTON DISTRICT.

(By permission of the Director of the Geological Survey and adapted from the 6-in. Geological Survey Map by W. A. E. Ussher, with some modifications.)

exposing limestone belonging to his lower division, dipping in a northerly direction at an angle of about 35 deg., and he obtained here specimens of *Heliolites porosus* and *Stromatopora hupschi*.

My notes on this section are as follow: The beds seen are crystalline bedded limestones, some layers more compact than others, but all obviously composed chiefly of crinoid fragments, and the prevalent colour of the rock is purple or purplish-grey. Stromatoporoid growths occur here and there, but sparsely, and corals are rare. The dip appears to be N.N.W. at 30 deg. or 35 deg. These limestones, as noted by Mr. Ussher, dip under grey and brown calcareous tuffs at the north end of the quarry.

Near the Palk Arms to the north-east Mr. Ussher found an out-crop of similar tuffs associated with shales which overlay even-bedded limestones, and he remarks: "It appears therefore that these limestones are lower than those in the Lummaton mass adjacent, and, if evidences of the superposition of shales and schalsteins upon them may be relied on, that there was here an interval during which local volcanicity and muddy sedimentation took place."

It occurred to me that if this view was correct some confirmation of it ought to be discoverable by a close scrutiny of the ground between Trumland's quarry and those on Lummaton Hill. Accordingly I examined the sides of the lane which skirts the eastern base of that hill, and nearly opposite Trumland's quarry and only 80 yards from the outcrop of the tuff I found an exposure of hard purple crinoidal limestone exactly like beds in the quarry. A little above this and in the field which forms the eastern slope of Lummaton Hill is a small overgrown excavation in and around which are scattered many lumps of dark grey and purple limestone and some fragments of *Stromatopora*. In one block I found the pygidium of a Trilobite, which has been examined by Dr. F. L. Kitchen and Dr. Ivor Thomas, who agree in referring it to the genus *Phacops*, but cannot determine the species, which is rather a large form. Pieces of similar limestone occur in the soil of the southern part of the field up to the edge of the grassland, just below the contour of 300 ft., and above this level light grey limestone crops out through the soil and appears also in a craggy face to the westward.

These facts prove the existence of grey and purple limestones on the eastern slope of the hill; they occur through a vertical height of about 70 ft. and a horizontal distance of about 250 ft. With a dip of 30 deg. this distance would bring in on the same level a thickness of 125 ft., so that there may be about 200 ft. of the lower bedded limestones on this slope. It is possible that the valley between this slope and Trumland's quarry is occupied by shales and tuffs, and that the limestones on the eastern side of the valley are entirely below those on the western, as Mr.

Ussher has surmised. On the other hand there may be a fault between the exposures, the limestones on the west being in that case a repetition of those on the east. For my present purpose it is sufficient to have shown that the lower limestones do enter into the structure of Lummaton Hill, and that they presumably dip to the N.W., so as to pass below the limestones of the well-known Lummaton quarries (see map, page 277).

If we ascend to the top of this eastern slope we look down into the first or most southern of the Lummaton quarries, and this is excavated entirely in a light-grey massive limestone, which is composed chiefly of Stromatoporoids, and in which no bedding is discernible. Brachiopods are seldom seen in this limestone.

We may reasonably suppose that the N.W. dip is still maintained, and this supposition is confirmed when we pass to the northern part of these eastern quarries, for west of a line which seems to run about S.S.W. to N.N.E. there is a gradual change from the Stromatoporoid limestone to a grey shelly limestone. There are faults here, and the rock in the upper part of the quarry face is largely dolomitised, so that it is not easy to make sure of any succession, but I shall describe what seem to be passage beds between these two limestone-facies. The shelly limestone yields many Brachiopods and other fossils.

In the more western quarries there are both shelly and crinoidal limestones, but even here no bedding is observable. In these quarries *Stringocephalus burtini* and *Rhynchonella cuboides* occur together, but at the north-west end certain corals are common which do not occur or are very rare in the eastern quarries.

From the evidence above given, therefore, I conclude that there is a definite succession from older to newer beds as one passes from the eastern to the western sides of Lummaton Hill; that the beds which crop out on the eastern slope of the hill belong to Mr. Ussher's lower division, but whether they are Givétian or Eifelian there is not sufficient evidence to decide. The beds in the quarries all belong to the Upper Limestone division of the same author, but there are certainly two different kinds or facies of limestone; the Stromatoporoid limestone only occurs in the south-eastern quarry and is therefore presumably older than the shelly limestone which has yielded the assemblage of fossils known as the Lummaton fauna.

3. Description of the Quarry-Sections.

There is no need to describe the relative positions of the quarries, for these can be seen by an inspection of the map. The southern part of the large eastern quarry has not been

worked for 7 or 8 years, the central part has been largely quarried during 1905 for road metal, and the northern parts were quarried for several years up till 1904, both for road metal and building-stone. The quarry at the north-western corner of the hill had not been worked for many years, but was re-opened in 1905, some of the stone being burnt for lime and some used for road-material. There is another old quarry south of the last which has not been worked for many years; most of it is dolomitic limestone, but a patch of shelly limestone occurs in one corner. Finally, a small quarry has been opened in dolomitic limestone still farther to the west.

It will be convenient to begin at the southern end of the eastern quarries. The floor of this excavation is nearly level, and I found it to be 40 long paces across—*i.e.*, about 120 ft.—while the western face is about 40 ft. high, so that if the dip is to the north-west and its amount about 35 deg. the total thickness of limestone brought in here will be about 90 ft.

The point which strikes the observer who visits this quarry in its present state is that the rock-faces have been weathered to an extent which is just sufficient to bring out clearly the component organisms of the rock; these being very little obscured by any dark staining or by growth of lichen, as is often the case in old excavations. As a consequence it is easily seen that this limestone is largely composed of *Stromatoporoid* growths. These organisms occur as lumps or masses of very irregular shape, some being more or less round or oval, but others sending out protuberances or forming elongate growths; they also vary in size from a few inches across to large masses 3 or 4 ft. in length. The largest which I measured was 4 ft. high by $2\frac{3}{4}$ ft. broad. Many of them show the concentric layers of growth very plainly, the commonest form having the characters of *Actinostroma stellulatum*, especially those of the third variety described by Nicholson, which seems to have grown outward in a series of close-set cylindrical or dome-shaped protuberances; so that in section they present beautiful patterns in curved lines or bands of alternating whitish and pale grey tints. *Stromatopora concentrica* is also common.

In many parts of the exposed surface the area occupied by *Actinostroma* and other *Stromatoporoids* represents more than half the mass of the rock, so that it is truly a *Stromatoporoid* limestone. They are easily distinguishable from the rest of the rock by their lighter tint and compact, homogeneous texture, even when they do not exhibit wavy or concentric lamellæ. The limestone material which fills up the spaces between the *Stromatoporoid* growths consists of broken pieces of *Favosites* and other corals, with fragments of crinoids, but shells of Mollusca or Brachiopoda are rare. Small growths of *Helicelites* are found, but are generally pieces which are overgrown by

Stromatoporoids, and look as if they had been killed by the enveloping growth of the latter.

The light-grey limestone can be followed northward along the north-western face of the quarry above a lower excavation, and is seen to pass into a grey rock in which Stromatoporoids do not form so large a part of the mass, though still very numerous. We then reach a place where much stone has been quarried during this year (1905), and here we find a limestone in which broken corals and various organic fragments occupy more space than Stromatoporoids. The upper part of the cliff has been altered into a white crystalline limestone by dolomitisation, and it is broken by a fault which rises steeply to the W.N.W., and is filled by a breccia of angular limestone fragments embedded in a matrix of reddish dolomite.

Returning to the floor of the quarry and passing northward we find a grey shelly limestone composed of Brachiopod shells, crinoid fragments, broken corals and bryozoa, with some scattered Stromatoporoids. The same kind of limestone is exposed in the next excavation to the north, which has been worked down to a lower level and carried farther also to the west. Here I noticed pieces of *Favosites* (*Pachypora*) *cervicornis*, a small *Cyathophyllum*, and a specimen of *Emmonsia hemispherica*, but there are no large pieces of coral, nor anything like coral-growths. Shell fragments seem to be abundant, though perfect shells are not common. The rock is certainly not coral-reef rock, but is simply a limestone made up of the various kinds of organisms that are likely to have lived and died on a sea-floor beneath no great depth of water. The largest organisms are still Stromatoporoids, but these are of moderate size (from 6 to 10 ins. across) and are of the more compact kinds.

Passing to the most northern branch of the quarry, which has also been carried still farther to the west, I found that the present face shows a grey shelly limestone occurring in patches surrounded by pale yellow and whitish crystalline limestone, both being traversed by veins and patches of red crystalline rock. Suspecting that these highly crystalline portions were more or less dolomitic, I desired to have analyses made, and for the following I am indebted to the kindness of Mr. G. S. Blake, of the Imperial Institute :—

		Pale Rock.	Red Rock.
SOLUBLE IN HYDROCHLORIC ACID.	Lime	32.46	29.31
	Magnesia	19.25	17.37
	Carbon-dioxide (including water)	46.60	42.92
	Ferric oxide } & Alumina }	.59	1.65
INSOLUBLE.	Silica	.42	4.62
	Alumina	.48	3.70
		99.80	99.57

Mr. Blake observes that if the proportions of lime, magnesia and carbonic acid are recalculated from the above quantities the relative amounts are found to agree very closely thus :—

	Pale Rock.	Red Rock.
Lime	33.01	32.71
Magnesia	19.58	19.39
Carbonic dioxide	47.41	47.90
	<hr/> 100.00	<hr/> 100.00

Moreover the proportions of these ingredients in the pale rock are almost exactly those of pure dolomite, and the principal chemical difference between the two rocks is the quantity of silicate of alumina present in the red rock.

The patches of grey shelly limestone occur irregularly both in the lower and the upper part of the cliff, and their borders merge into the dolomite in such a way as to make it clear that the shelly limestone represents the original condition of the mass and that these patches are simply the unaltered portions of the rock.

It is from this grey shelly limestone that the well-known Lummaton fauna has been obtained, and it was from a weathered patch of grey rock at the top of this quarry that Mr. Whidborne obtained a large number of the specimens in his collection. He informs me, however, that this patch appeared to be a portion of a special bed which consisted chiefly of small and young shells, with very few of the larger species of Brachiopoda. Most of the patches of shelly limestone do not contain these small shells, but yield *Stringocephalus burtini*, *Rhynchonella cuboides*, *Spirifera curvata*, and other shells of similar size. Crinoids, or rather crinoid fragments, are very abundant in this limestone and are often the most obvious components; corals occur, but the only species that is common is *Pachypora cervicornis*. Stromatoporoids are also very common, but are seldom of large size.

No part of this limestone resembles coral-reef rock such as I have seen in the raised reefs of Barbados. Corals are not more abundant in it than are Stromatoporoids, and none of the corals which occur in the Torquay limestones have the aspect of modern reef-building corals; even the growths of *Smithia* and *Acerularia* are seldom more than 7 or 8 ins. across, and where corals are abundant they are generally limited to definite beds, and seem to be merely the remains of coral-fields or growths on the sea-floor.

No bedding can be distinguished in this limestone; it is massive, but traversed by joint planes which cross one another and break it into angular blocks. Movement has taken place along some of the master-joints, the faces of which show slickensides. The western face of this quarry intersects another fault which seems to run nearly parallel to the one previously mentioned,

and like it is filled with fault-rock consisting of red dolomite, enclosing fragments of the white and yellowish dolomite.

Here and there are pockets or cavities filled with what looks like red sand, but this is merely decomposed and disintegrated dolomite, consisting entirely of broken rhombic crystals, without any admixture of quartz sand. Some of these pockets when cleared out are big enough for two men to stand up in.

The western face of the quarry last mentioned is only separated by a strip of ground about 50 ft. in width from another, which I shall call the north-western quarry. This has also been largely worked in 1905, and the limestone in its eastern part is the same as that just described. Parts of it are dolomitized, but the larger part is unaltered. Brachiopods are common, especially *Stringocephalus burtini*, *Spirifera curvata*, *Rhynchonella cuboides*, and *Atrypa reticulata*. A Stromatoporoid which I take to be *Actinostroma hebbornense*, forming compact dark grey masses, is also abundant, but I did not see any corals except the usual small pieces of Favosites (Pachypora).

The western part of the quarry exhibits limestone of more varied composition, though even here it is difficult to make out any definite beds. It seems rather to vary in a patchy way, some portions being full of *Pachypora cervicornis*, and others being largely composed of crinoid-fragments and Brachiopod-shells. Other parts are of finer grain and seem to consist of a fine matrix in which the small arm-ossicles of crinoids are abundant. In all parts Stromatoporoids are not uncommon, but they are not specially numerous.

Along the western side, however, certain corals come in which are either absent or rare to the eastward; these are *Smithia hennahi* and *S. pengellyi*, the former being the most abundant. This fact is interesting because these corals are characteristic of the limestone found in the Barton quarry about half a mile to the N.E. of this point.

South of the last quarry there is another old excavation in dolomitic limestone with a patch of unaltered but much weathered grey limestone at the top of the eastern corner. It is from this patch that many of his fossils, as Mr. Whidborne informs me, and especially the Trilobites, were obtained. This appears to be similar to the other fossiliferous patch and, like it, contains many small Brachiopods, such as *Centronella virgo*, *Magellania juvenis*, and *Merista plebeia*. It is possible that these patches are portions of lenticular beds or shell banks arranged by the action of currents, but I see no reason to regard them as "littoral deposits" or as "shell heaps" in any other sense than that above expressed.

If the dip in these northern quarries is at all steep there must be a considerable thickness of these shelly limestones. Along a line measured from S.S.E. to N.N.W. there is a space of about

400 ft. occupied by them, and if the dip is only 30 deg. this will bring in a thickness of 200 ft., provided that there is no duplication by faults.

Summary and Conclusions.

This account of the limestones of Lummaton Hill has been written because no adequate description of them had been published, and because I had found that three different types or kinds of limestone entered into the structure of the hill and occurred in a definite order. Whether they form a complete succession or one broken by faults can only be determined by comparison with other localities.

I claim, however, to have shown that limestones belonging to the lower division of the series form the basal part of the eastern slope of the hill. These beds presumably dip to the N.W. below the limestones exposed in the quarries, for the line of junction appears to strike in a N.E. direction, but I cannot say that this is not a line of fault.

The next point of importance is the recognition of a limestone which is mainly composed of Stromatoporoids. Nicholson in the Introduction to his monograph on these fossils* remarked that "whole beds of Silurian and Devonian limestone being often essentially made up of the remains of these organisms," but he does not seem to have been aware that any of our own British limestones were so composed. On the continent, and especially in Belgium, "Stromatoporoid limestones" have long been known to occur both in the Givétian (Middle Devonian) and in the Frasnian (Upper Devonian) limestones. It is therefore high time that such limestone was recognised in this country as a definite limestone facies and as a component of our Devonian System, for it has a character of its own which is quite as striking as that of coral-limestone or crinoid-limestone. Moreover, its recognition is likely to be useful in establishing a succession at other places near Torquay, for similar limestone occurs in the cliffs south of Babbacombe, and Mr. Ussher mentions "limestones rich in Stromatopora" near Goodrington,† but these latter I have not yet seen.

I think it is largely owing to the massiveness imparted by the large Stromatoporoids that the absence of bedding is due, for this limestone was evidently formed by the filling-up of the spaces between the Stromatoporoid growths, so that anything like stratification was almost impossible.

With regard to the third type of limestone, which has been described as "coralline," and even as "part of a coral-reef," I have shown that it does not contain any corals which by their

* *British Stromatoporoids*, *Pal. Soc.*, Part 1, p. 29, (1885).

† *The Geology of Torquay*, *Mem. Geol. Surv.* p. 74, (1903).

size and manner of growth bear any resemblance to modern reef-building corals. Even some of the pieces of *Smithia* which occur, both in the Lummaton and Barton quarries, are obviously broken fragments embedded in the limestone, and did not grow where they are now found. The remains of corals do not form so large a part of the rock-mass as they do in modern reefs, or as Stromatoporoids do in the adjacent limestone. As a matter of fact the rock in question is not a coralline limestone but a shelly limestone, consisting mainly of the broken remains of Crinoids and Brachiopods.

We know from the experience of the naturalists on board the "Challenger" and the U.S. steamship "Blake," that Crinoids often grow in large colonies which cover wide spaces on the sea-floor. Parts of this shelly limestone suggest that they were formed by such colonies or fields of Crinoids, among which also grow the branching *Pachypora cervicornis*, while attached to the bases of both were the various Brachiopods and Bryozoa which are so common in this limestone. All these creatures may have lived and died together on the floor of a sea which was neither shallow nor very deep, but suited to the quiet growth of the Crinoids and of the delicate Bryozoa.

Another point of interest in the Lummaton quarries is the transformation of large parts of this shelly limestone into dolomite, for all the local evidence points to the conclusion that this alteration of the limestone was effected by the waters in which the Permian Beds were deposited.

The dolomite is only found in the western part of the hill, on which side the limestone passes directly under the Permian Beds; it does not occur on the eastern side, which slopes to the valley and has been exposed in comparatively recent times. Again, the red dolomite which fills the fissures and faults in the limestone is evidently coloured by a red clay which seems to have been carried in and disseminated along with the water which effected the dolomitization of the rock. Now the lowest Permian deposit in the neighbourhood is the fine red clay of Watcombe, which has long been worked for making terra-cotta ware. It is this clay which overlies the limestone on the west, and it is therefore a reasonable inference that the alteration of the limestone was accomplished either just before or during the time when this red clay was being deposited on the top of it. Very probably the light-coloured dolomite was formed before the red clay was brought into the area, and the red rock was of subsequent formation, for it certainly penetrates the former as if this was the case.