13. *The* Carboniferous Rocks *at* Rush (*County* Dublin). By Charles Alfred Matley, D.Sc., F.G.S. *With an* Account *of the* Faunal Succession *and* Correlation. By Arthur Vaughan, B.A., D.Sc., F.G.S. (Read December 20th, 1905.)

[Plates XXIX & XXX—Fossils.]

Contents.

I. Introduction. [C. A. M.]

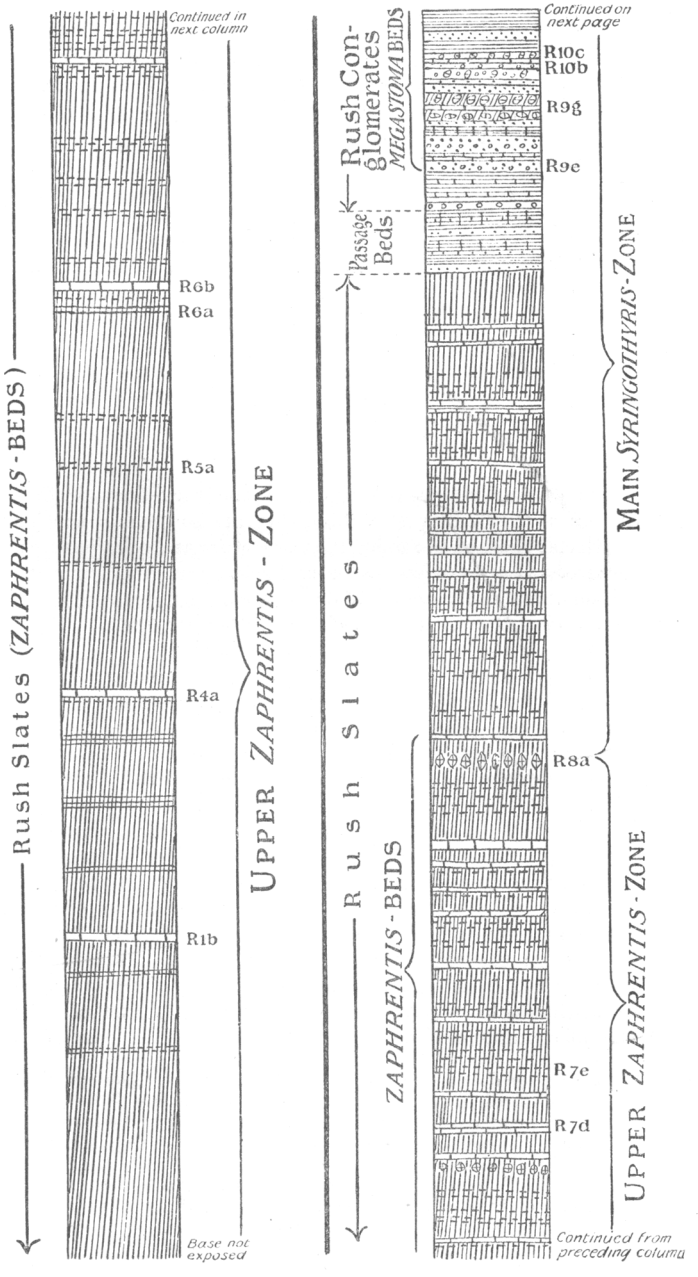
Although Carboniferous rocks form the rock-floor of the greater portion of the County of Dublin, they are so much concealed inland by Glacial Drift as to render their structure and relationships usually obscure. On the coast, however, they crop out in several very good sections, especially near Malahide, about 4 miles north of Dublin Bay, and at Rush, about 6 miles still farther north. The latter is the more extensive and interesting of these two.

From the shore south of Rush village, extending northward past Loughshinny to within a mile of Skerries—a distance in all of about 5 miles — the Lower Carboniferous rocks are splendidly exposed: the outcrops being only interrupted occasionally, where the shore is covered by sand, or the Glacial Drift descends to sea-level. At the suggestion of Mr. G. W. Lamplugh, F.R.S., and tempted by the interesting character of the rocks themselves, I was induced (during a temporary residence in Ireland) to make a detailed examination of these beds. In order to understand the coast-section in full detail, a horizontal section of the beds, as shown in the cliffs and along the rocky shore, has been prepared for the whole distance on the scale of 1 inch to 10 feet.[1] As, however, fossils have up to the present been collected only from the rocks near Rush, that is to say at the southern end of the line of section, the present communication will be restricted to that part of the area;

[1] The section does not pretend to absolute accuracy. The base-line has been roughly measured on the ground with a 10-foot string weighted at one end by a stone, the details of the exposure being sketched in at the same time. But the scale is sufficient to allow of all the important beds being shown and the structure being recorded in considerable detail, while the horizons from which the fossils have been obtained are thus fixed with much precision. The thicknesses of beds, as given in the following pages, are calculated from the section and checked with the 25-inch map. The margin of error should, therefore, not exceed 10 per cent.

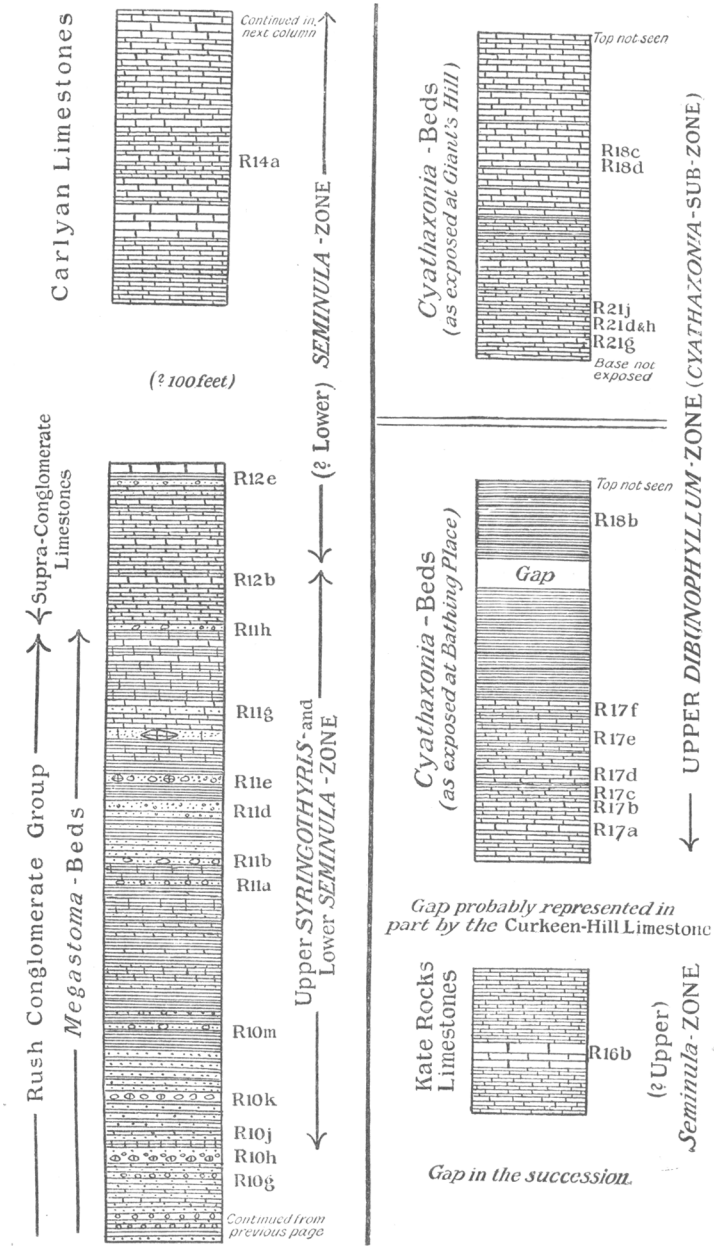
Fig. 1.—*Vertical section of the Carboniferous rocks*

[The notation on the right of the section refers to fossiliferous



at Rush, on the scale of 120 feet to the inch.

beds the fauna of which is enumerated in the faunal lists. pp. 295–99.]



but I hope to present an account of the remainder of the section in a future paper.

The description of these beds in the Explanatory Memoir of the Geological Survey of Ireland (Sheets 102 & 112)[1] seems to be the only detailed account that has hitherto been published. In G. V. Du Noyer's section on p. 62 of that memoir, all the beds at the Rush end of the coast-section are lettered *d 4*, except a small patch of black shale south of Brook's End which is marked *d 5*, and this notation agrees with that in the 1-inch Geological Survey-map (Sheet 102, revised 1901); but *d 5* is absent from the index of the map, and the beds so marked are coloured as though they were the '*d 3* & *d 4* (Millstone Grit & Yoredale Beds)' of the index; while, to add to the difficulty of reading the map, the *d 4* areas are coloured to correspond with the '*d 2* (Calp)' of the index. It may be presumed, however, that the colouring, and not the lettering, indicates the current opinion of the officers of the Survey as to the age of the beds at Rush.[2]

The term Calp is used by the Geological Survey to include in this particular area both the true Calp (Middle Limestone) and the Upper Limestone, as the latter is believed to have taken on a 'calpy' character here, and thereby to have become indistinguishable lithologically from the Middle Limestone.

Palæontology has hitherto been of little service in separating the beds, but, as will be shown below, Dr. Vaughan has now ascertained, from an examination of the fossils of the Rush sequence, that the same faunal succession is to be found, with slight modification, on both sides of St. George's Channel, and he has been able to subdivide the beds into palæontological zones corresponding with those that he has already described from England and Wales.

II. General Structure and Sequence. [C. A. M.]

The Carboniferous beds of Rush are separated on the south, from the Ordovician and Old-Red-Sandstone inlier of Portraine[3] by the mouth of an estuary 1½ miles wide, and on the south-east, from the somewhat similar rocks of Lambay Island[3] by 2½ miles of sea.

[1] 2nd ed. (1875) pp. 61-66.

[2] On my making enquiries of Prof. Grenville Cole, F.G.S., who now has charge of the Irish Geological Survey, he has been good enough to explain how the confusion between lettering and colouring has come about. It appears that, when Sheet 102 was originally issued in 1859, certain outliers of 'Coal-Measures' (the *Posidonomya*-Beds) were coloured on it in the Rush area. When revised about 1875 the 'Calp' anticlinals along the coast were inserted, but without the removal of the letter *d 4*. In the index the Calp is marked *d 3* & *d 4*, and the Upper Limestone *d 4* also. At a later revision the 'Coal-Measure' area was coloured 'Millstone Grit & Yoredale,' and some of the *d 5* marks were altered to *d 3*, the margin showing 'Millstone Grit & Yoredale Beds' as *d 3* & *d 4*. But *d 4* was allowed to remain on the Calp anticlinals, which now should have been lettered *d 2*. Prof. Cole adds that it is intended to rectify the discrepancies in the map at an early date.

[3] For an account of the rocks of Portraine and Lambay Island see C. I. Gardiner & S. H. Reynolds, Quart. Journ. Geol. Soc. vol. liii (1897) p. 520, & vol. liv (1898) p. 135.

To the north, at Skerries and at Shenick's Island, Llandovery Beds with a small patch of Old Red Sandstone are also found; consequently, the general structure of the Carboniferous rocks between Rush and Skerries, although complicated by much folding and by some faulting, must be that of a syncline.

There is a general upward succession of the beds exposed near Rush, as they are traced from south to north; and the sequence, in descending order, is as follows:—

Stratigraphical Zones.		*Thickness in feet.*	Palæontological Zones.
Cyathaxonia-Beds.	Limestones, sometimes cherty, containing chert-seams, interstratified with shale, and decomposed locally into decalcified beds.	200	Upper *Dibunophyllum*-Zone (*Cyathaxonia*-Subzone).
[Gap, probably occupied in part by the horizon of the limestone of Curkeen Hill, mentioned on p. 294.		?	Upper *Dibunophyllum*-Zone.]
Kate-Rocks Limestones.	Thickly-bedded limestone, underlain and overlain by thin calcareous dark shales and thin limestones. Some chert-seams.	90	(? Upper) *Seminula*-Zone.
[Gap]		?	
Carlyan Limestones.	Thickly- and thinly-bedded dark-grey limestones, occasionally pebbly, with calcareous flaggy beds.	180	(? Lower) *Seminula*-Zone.
[Gap		?100	Gap]
Supra-Conglomerate Limestones.	Flaggy limestones sometimes pebbly, with partings of black shale.	100	*Feet.* 70 Lower *Seminula*-Zone. 30 Upper *Syringothyris* & Lower *Seminula*-Zone.
Rush Conglomerate Group.	Conglomerates, sometimes very coarse, usually having a limestone-matrix and interstratified with shales and calcareous sandy flags.	500	330
Passage-Beds.	Calcareous sandy and shaly beds.	40	170 40 The Main *Syringothyris*-Zone.
Rush Slates.	Black slates, often calcareous and nodular, with occasional limestone-bands & lenticles.	1380	300 1080 Upper *Zaphrentis*-Zone.
	(Base not seen.)		

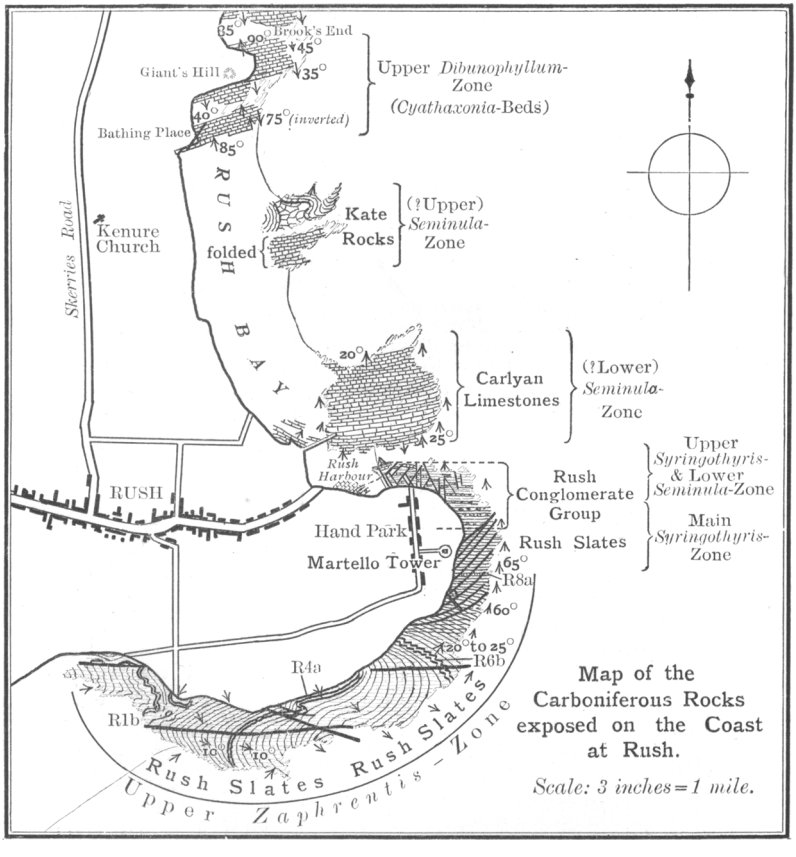
The rocks will now be described in ascending order.

III. Description of the Rocks. [C. A. M.]

(*a*) The Rush Slates and Passage-Beds (*Zaphrentis*-Beds).

The Rush Slates are well exposed, when the tide is out, on the shore south and south-east of Rush. They consist of black and dark-grey, well-cleaved argillaceous slates, with numerous bands of dark, less perfectly-cleaved, calcareous slate, sometimes containing nodules

Fig. 2.



of impure limestone or intercalated with occasional well-defined bands of moderately-pure limestone. Their base is not exposed. The lowest beds visible are seen emerging from the sandy beach at the western extremity of the rocky shore; and there is a general upward succession as the beds are followed along the coast, first eastward and then northward towards Rush Harbour, before

reaching which place they are seen to pass upwards into the Rush Conglomerates. The strike of the rocks on the southern shore (see fig. 2, p. 280) forms a sigmoidal curve, and the beds are arranged in an elliptical basin followed on the north by an elliptical dome, the long axis of the basin running in an approximately east-and-west direction and having an easterly pitch. The principal axis of the folding corresponds with the strike of the cleavage.

At the western end of the outcrop, in the neighbourhood of the well called Tobberkilleen, and at a horizon about 200 feet above the lowest visible bed, there is a band of limestone [R 1 *b*][1] containing a few fossils. It sometimes stands out from the neighbouring slates in small dome-like elevations, and can be traced as a broken and twisted band for some distance, until it becomes lost in a mass of nodules which seem to be the result of the disintegration of the limestone by the forces that produced the cleavage. A second well-defined limestone-band [R 4 *a*] occurs some 150 feet above the first, and a third [R 6 *b*] is found about 250 feet above the second. Their peculiar outcrop will be described later.

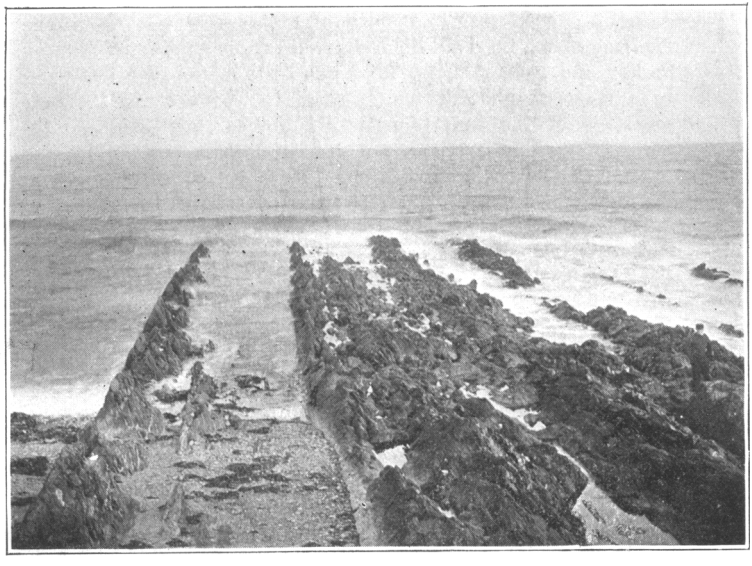
These lower beds of the Rush Slates (that is, up to the third limestone-band R 6 *b*) have a curved strike and a rather low dip, usually from 10° to 20°. They form a low rocky shore, almost wholly below high-water mark, the argillaceous slates having a rather smooth aspect, while the more calcareous zones weather with ragged edges. To make out their general structure is an easy task; but the details give much more trouble, owing to the frequent obscuration of the bedding by cleavage, to the growths of seaweed on the rocks, and to the monotonous character of the beds themselves. Several fault-lines can, however, be traced in the slates; but the fractures all appear to have a very slight throw, and do not affect the general stratigraphy.

Near the third limestone [R 6 *b*] the coast-line changes in direction, and turns northward. This change is accompanied by a rapid increase in the dip of the beds up to 60° or 65°, and at the same time the curved strike straightens out so that the beds run very regularly in an east-and-west direction. This change in strike is naturally accompanied by some displacement of the beds, and accordingly a number of sub-parallel faults, with some connecting fractures, can be seen here running in a direction a little to the north of north-east; but their throw is insignificant, varying from a few inches to a few feet. A large nest of calcite, on the shore near high-water mark, marks the intersection of two of these faults. The strike of the beds is now at right-angles to the coast-line, and the scenic effect here is quite different from that of the beds on the southern shore. The rocks now present a series of sharp ridges running out to sea, steeply inclined on the northern or dip-face, and but slightly broken by the small cross-faults just mentioned. The ridges are separated from each other by sharply-defined gullies, where

[1] The notation R 1 *b*, R 4 *a*, etc. refers to the horizons as shown in the vertical and horizontal sections, and catalogued in the faunal lists.

sea-erosion has channelled out the softer and more argillaceous beds (see fig. 3, below). It should be noticed that the erosive action of the sea here follows the bedding-, not the cleavage-planes, this being due to the fact that while the soft argillaceous beds are still well-cleaved, the harder calcareous bands are only imperfectly fissile in the cleavage-direction.

Fig. 3.—*Upper Rush Slates, on the shore south of Rush Harbour, looking eastward.*



[The beds dip steeply northward, while the cleavage dips steeply in the opposite direction. The strike is east and west. The softer argillaceous beds are eroded, leaving the calcareous beds standing out as ridges.]

The upper slates above the third limestone-band [R 6 *b*] are more calcareous than those below. Nodules and lenticles of impure limestone are found in them at many horizons; while seams and beds of purer limestone which have resisted cleavage are occasionally intercalated. About 480 feet above R 6 *b* is a prominent bed [R 8 *a*], some 6 feet thick, composed of lenticles of limestone (one of them 5 feet thick) embedded in a black slaty matrix. The slates continue for about 300 feet above this zone, and then pass, after about 40 feet of Passage-Beds, into the Rush Conglomerates. Pebbles in the upper portion of the Rush Slates, although decidedly rare, are occasionally to be found, and there is a 1-inch seam [R 9 *a*] of fossiliferous limestone containing numerous tiny quartz-pebbles as low down as 120 feet below the Passage-Beds.

The Passage-Beds, about 40 feet thick, are intermediate in character between the Rush Slates and the Rush Conglomerates.

They consist of black shales, sometimes calcareous, interstratified with thin flaggy bands of sandy limestone containing quartz-pebbles and rock-fragments, for the most part of small size. Cleavage is beginning to die out, and is weak, except in the basal beds.

Fossils have been collected from various horizons in the Rush Slates, and those sufficiently well preserved to be identified are recorded on a later page (p. 295). The lowest 200 feet have not yet yielded fossils; but they may be provisionally grouped in the same zone as the overlying beds. The beds between R 1 *b* and R 8 *a* seem to belong to the 'Upper *Zaphrentis*-Zone (Z 2–γ)' of Dr. Vaughan, their upper portion (R 6 *b* to R 8 *a*) containing a typical 'γ' fauna. From R 8 *a* into the overlying conglomerates the beds are assigned to the 'Main *Syringothyris*-Zone' (C). The typical fossil of all these beds is *Zaphrentis* cf. *Phillipsi*, Edw. & H.

Before passing on to the description of the Rush Conglomerates, the more striking effects of compression on the Rush Slates ought to be noticed. The shallow basin of Lower Slates on the southern shore is crossed, as already stated, by cleavage striking nearly east-and-west, with the result that over the larger part of the exposures there is a marked discordance between bedding- and cleavage-strikes. Owing to the fact that the shales have yielded to compression more than the limestone-bands, the latter have usually been crumpled at right-angles to the cleavage-strike, in order to reduce their horizontal extent. Fig. 4 (p. 284) shows the lobe-like extensions which this oblique direction of compression produces on the outcrop. It will be noticed that the detailed folding of the bed is quite discordant with the general dip. Occasionally the folding is so pronounced as to produce a slight inversion of the bed, and the concave surfaces are puckered into minute corrugations. The crumpling dies out in the slates in a very few feet vertically above and below the crumpled bed. From a measurement, necessarily rough, of the surface of the limestone taken across the folding, it appears that 5 feet of limestone corresponds to about 3 feet of slate; and, as this would represent the minimum compression, we may infer that the slates have been reduced by nearly one-half their original extent across the cleavage-strike. One effect of the compression on the slates is that their thickness will be found to vary if measured in different directions, being least where the bedding-strike coincides with the cleavage-strike, and greatest where the two strikes are at right-angles.[1]

The augen-like nodules of impure limestone which are common in

[1] The peculiar stratigraphical features of these limestone-bands, although occurring on a small scale and in other ways exhibiting considerable differences, are recommended to the notice of geologists interested in the much-debated structures of limestone-knolls. Substitute for the thin bands in the Rush Slates a massive but flexible limestone lying between masses of more compressible strata, and for the overlying Rush Conglomerates substitute a thick mass of Millstone Grit, and subject the whole to powerful compression: then one may expect as a result, that the surface of the limestone will be thrown into folds which would be locally unconformable to the adjacent strata, and that about the junction some brecciation may be looked for.

the slates are so arranged, that their long axes lie in the direction of cleavage. Usually they are imperfectly cleaved, and their edges are tailed out into thin plates. Several adjacent nodules at one spot were found to measure as much as 36, 40, and 63 inches respectively along the cleavage, though none of them exceed 7 inches across the cleavage. They are clearly deformed by the compression, but their length in comparison with their width is so great that it is difficult to regard them as of ordinary concretionary origin. Although it would be rash to dogmatize in the case of such rocks as limestones, in which concretionary structure is so common, and is no doubt the origin of many of the nodules at Rush, I am convinced that in numerous instances the lumps of limestone lying in the Rush Slates were once portions of bands that have been broken up by movement, which has squeezed the soft shale of adjacent beds into the interstices between the separated fragments. A reference to fig. 4 shows that a mass of nodules is associated with the limestone-band R 4 *a*, and this the writer regards as a broken-up part of the band lying in a synclinal fold. Other instances occur of thin limestone-bands in the slates, slightly oblique to the cleavage, being converted into a connected string of phacoids elongated along the cleavage-planes. In the higher part of the slates, where the dip is high, the limestones break up into phacoids which are, however, practically continuous one with the other.

Fig. 4.—*Plan of a limestone-band [R 4 a] in the Rush Slates, showing the effect of oblique cleavage-strike on the outcrop of the limestone.*

(*b*) The Rush Conglomerate-Group (*Megastoma*-Beds).

These consist of numerous beds of very regularly-stratified conglomerate, occurring singly or several together, and separated by narrow or wide intervals of sandy calcareous flags, sandy and pebbly limestone, and laminated shale.

The most conspicuous of the conglomeratic bands usually vary from 2 to 4 feet in width, while one [R 10 *h*] is nearly 12 feet thick. They dip steadily northward in conformity with the underlying beds at angles of 50° to 65°, and they are broken by numerous small faults, which are well displayed on the shore close to Rush Harbour (see fig. 6, p. 287). The included pebbles are, as a rule, fairly well water-worn, their angles and frequently their whole surface being rounded. In some bands the inclusions are small, not exceeding the size of a hazel-nut; in others they are considerably larger; while in some beds very large pebbles abound, frequently exceeding 1 foot in length. One pebble measured 26 × 22 inches, another 32 × 14 × 10 inches, and even larger ones could probably be found by more exhaustive search. They consist for the most part of white quartz, grits and slates of various colours, andesitic rocks, and limestone, and are usually embedded in a limestone-matrix in which corals, brachiopods, crinoid-fragments, and other fossils are not infrequent.

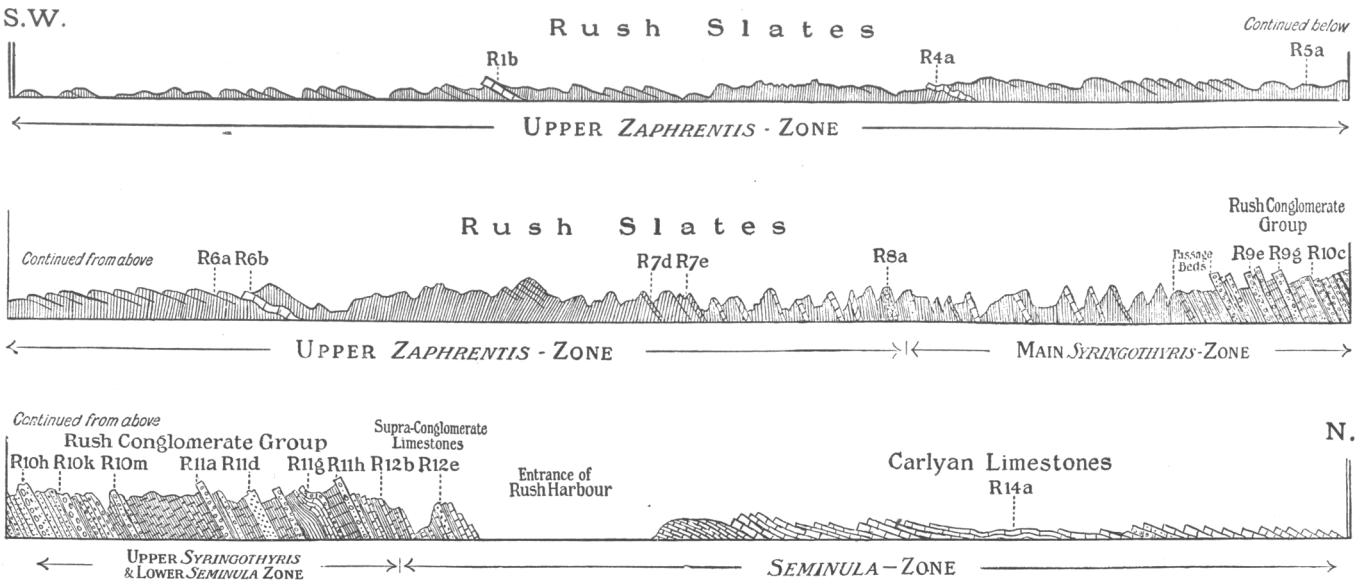
With the exception of the limestone-inclusions, the origin of the pebbles is easily referred to the Ordovician and Silurian rocks of the neighbourhood. Such rocks are now found *in situ* at Portraine on the south, and near Skerries on the north. The limestone-pebbles, which predominate largely in some of the beds, present more difficulty. Although it is possible that a few of them may be derived from the Ordovician limestone of Portraine, the very great majority are undoubtedly of Carboniferous-Limestone age. Now, the Rush Conglomerates and the Pendine Conglomerate of South Wales are shown, by the zonal work of Dr. Vaughan, to be on the same horizon (*Syringothyris*-Zone). The latter conglomerate also contains Carboniferous-Limestone pebbles, which are thought, from fossils found in them, to have 'been derived from a horizon probably not higher than a low part of the *Zaphrentis*-Zone.'[1] To regard the Rush Conglomerate-Group, like the Pendine Conglomerate, as an 'intra-formational conglomerate'[2] in respect to its limestone-pebbles, seems to be on the whole the most satisfactory explanation of the presence of these inclusions. The few fossils found in them have, as yet, yielded no clear evidence as to the horizon from which they have been derived; but, so far as it goes, it implies very little or no difference of age. The occasional presence of small pebbles in these inclusions suggests, however, that they may be of contemporaneous or almost contemporaneous horizon, or may in some cases have been formed *in situ*. One limestone-inclusion, occurring as a lenticle 7 feet long by 4½ feet wide, in a bed of very pebbly limestone [R 11 *f*], must certainly have been formed in place.

The conglomerates have greatly interfered with the action of the cleavage that has had so marked an effect on the Rush Slates. Not only are they quite unaffected by it themselves, but they have almost completely protected the beds intercalated in them, even the

[1] 'Summary of Progress of the Geological Survey for 1904' Mem. Geol. Surv. 1905, p. 44.

[2] *Cf.* C. D. Walcott, 'Palæozoic Intra-Formational Conglomerates' Bull. Geol. Soc. Amer. vol. v (1894) pp. 191–98.

Fig. 5.—*Horizontal section through the Rush Slates to the Carlyan Limestones.*



[Horizontal scale : 25 inches =1 mile. The vertical scale and the thickness of individual beds are exaggerated.]

Fig. 6.—*Sketch-map showing the faulting of the Rush Conglomerates at Rush Harbour.*

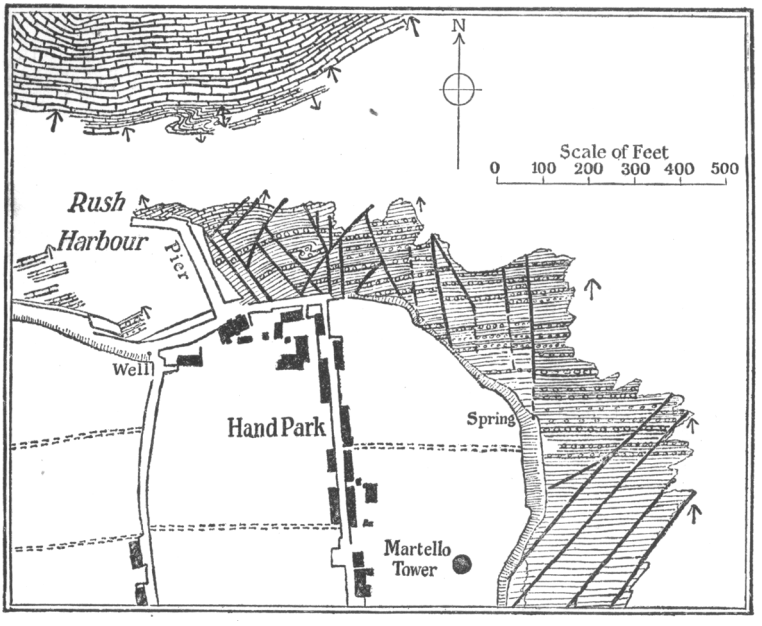


Fig. 7.—*Rush Conglomerates, near Rush Harbour, showing the size of the inclusions of Ordovician (or Silurian) rocks in the coarser conglomerate-bands (Upper* Syringothyris- *and Lower* Seminula-*zone).*

x 2

fine shales being cleaved but occasionally, and then imperfectly. There is, moreover, very little good cleavage in any of the beds to the north of the Conglomerate-Group[1] for some distance, and then only on a small scale.

Correlating the Rush Conglomerate-Group on the evidence of the fossils, Dr. Vaughan regards the lower beds (about 160 feet) as probably belonging to the 'Main *Syringothyris*-Zone,' and places the upper beds (about 340 feet, commencing with the thick conglomerate-bed [R 10 *h*]) in the 'Upper *Syringothyris*- and Lower *Seminula*-Zone.' This determination of their horizon brings out the interesting fact that these conglomerates are synchronous with the Pendine Conglomerate[2] of South Wales, and approach the horizon of the volcanic rocks of Weston-super-Mare.[3] It seems, therefore, probable that the Mid-Avonian disturbance and elevation, hitherto recognized only in the South-West of England and Wales, was not a local phenomenon, but was possibly part of a movement extending over a wide area.

Another remarkable conglomerate intercalated in Carboniferous Limestones occurs on the coast at Point Lane, $2\frac{1}{2}$ miles north of Rush, between Loughshinny and Skerries, the contemporaneity of which with the Rush Conglomerates is discussed in the Geological Survey-memoir (*op. cit.* p. 66). This question has yet to be investigated, but it seems likely that the Point-Lane Conglomerate will prove to be on a much higher horizon.

(*c*) The Supra-Conglomerate Limestones.

The upper boundary of the Conglomerate-Group has been taken at a 5-foot conglomerate bed [R 11 *h*], with a 14-inch pebbly band on its upper surface. The succeeding beds are for the most part thin, flaggy and shaly limestones, and dark calcareous flags with, especially towards the top, occasional thicker beds of limestone, sometimes 2 feet thick. They contain several pebbly horizons, and there is a 2-foot pebbly limestone [R 12 *d*] near the top. The bed [R 12 *e*] immediately overlying this contains plant-remains, but these are in so poor a state of preservation that Mr. R. Kidston, F.R.S., who kindly examined them, can only say of them that they have 'a fern-like look.'

These limestones, etc. have the high northerly dip (60° to 65°) of the underlying group, and their outcrop terminates at the entrance to Rush Harbour. About 100 feet of beds are seen, 30 feet of which are assigned to the Upper *Syringothyris*- and Lower *Seminula*-Zone. No zonal fossils have been collected from the uppermost beds, which probably belong to the same zone.

[1] It may be remarked, in passing, that this area appears to be the most northerly spot in the British Isles in which cleavage occurs in beds of so late a period as the Carboniferous. The occurrence of cleavage so far north may be connected with the deflection of the general lines of Armorican folding in the South of Ireland by the great mass of the Wicklow Granite.

[2] 'Summary of Progress of the Geological Survey for 1904' Mem. Geol. Surv. 1905, p. 44.

[3] C. Lloyd Morgan & S. H. Reynolds, Quart. Journ. Geol. Soc. vol. lx (1904) p. 148.

(*d*) The Carlyan Limestones.

These beds are separated from those last described by the entrance to Rush Harbour; and, although a gap of only 200 feet divides the two series, there is a marked difference in the lie of the beds. On the south side of the harbour, the Upper Rush Slates, the Conglomerate-Group, and the Supra-Conglomerate Limestones have been dipping steadily at angles of 50° to 65°; while on the north side the Carlyan Beds undulate at low angles, though with a general northerly dip. From this marked change of dip, and from the fact that the numerous small faults seen on the south side of the harbour are not traceable across the harbour-entrance, and that there is some disturbance of the beds, seaward, on the north side, it seems probable that there is a strike-fault here, though of no great throw, as the two sets of rocks correspond closely in lithological character. If there is no fault, the top of the Supra-Conglomerate Limestones is about 100 feet below the horizon of the Carlyan Beds.

The latter consist of dark-grey, well-bedded limestone, and dark calcareous and argillaceous flaggy beds, which at several horizons are charged with numerous small fragments of slate and other rocks. They are quarried locally for building-purposes. They occupy a low rocky shore covered at high tide, and disappear northwards under the waters of Rush Bay at an angle of 15° to 20°, after exposing about 180 feet of beds.

Fossils are by no means abundant, and the few that have been collected are unsatisfactory for zonal purposes. They probably belong, either to the Lower, or to the Upper *Seminula*-Zone.

(*e*) The Kate Rocks.

These are low weed-covered rocks, projecting from the sands of Rush Bay, and are only accessible at low tide. They are separated from the Carlyan Rocks on the south by 300 yards of sandy beach, and by nearly the same distance from the *Cyathaxonia*-Beds on the north. They comprise a set of thickly-bedded limestones, underlain and overlain by thin, laminated, black, calcareous shales and thin limestones. They contain moreover some chert-seams, and rock-fragments have also been found in the limestone.

These beds are disposed in a rapid succession of sharp folds, which are often slightly overfolded, with the crests of the anticlines turned towards the north. Fig. 8 (p. 290) shows a section across these beds. Owing to the complicated structure, the exact thickness of the beds has not been ascertained; but probably about 90 or 100 feet are exposed, of which some 15 feet would consist of the thick beds.

At present, fossil evidence is too meagre to allow of these beds being correlated precisely. They are, in all probability, intermediate in age between the Carlyan Limestones and the *Cyathaxonia*-Beds now to be described. Their occasionally-included rock-fragments connect them with the former, and their chert-seams with the latter.

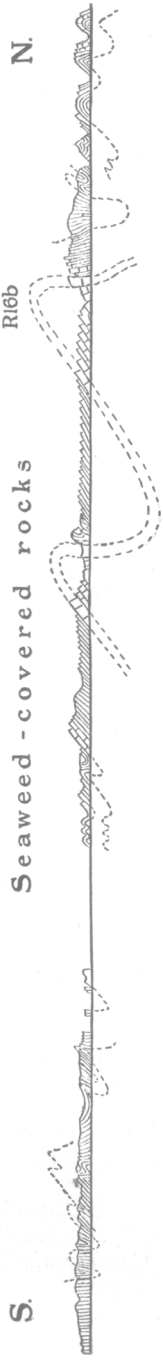


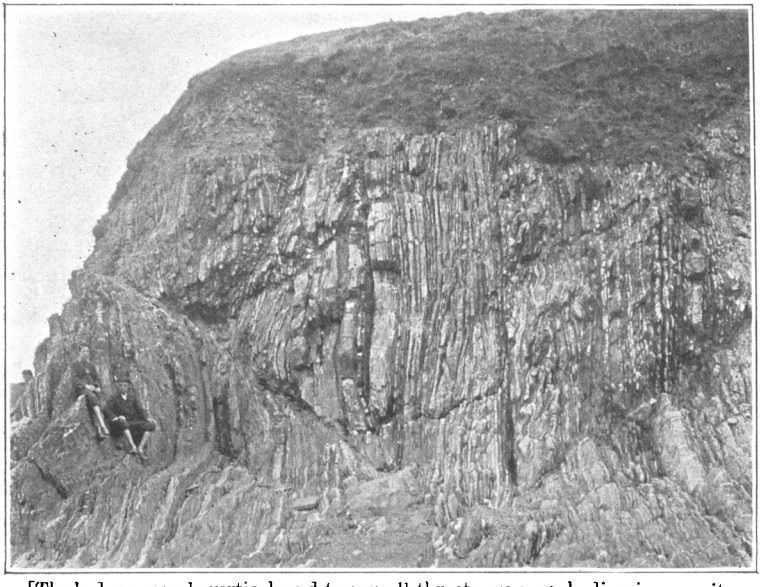
Fig. 8.—*Horizontal section through Kate Rocks, to show the folding of the limestones. (Length of section = about 175 yards.)*

(*f*) The *Cyathaxonia*-Beds.

These beds, which extend northward from the Bathing-Place, on the north side of Rush Bay, past Giant's Hill and Brook's End (where the section, so far as the present paper is concerned, finishes), are characterized by containing a highly-specialized coral-fauna in which species of *Cyathaxonia* are dominant, and they form a special phase of the Upper *Dibunophyllum*-Zone which Dr. Vaughan proposes to call the *Cyathaxonia*-subzone. The beds consist in part of evenly-bedded limestones with partings of shale, and in part of thin limestones, usually earthy-looking, and arranged in beds only 1 to 3 inches thick, though several such beds are often welded together to form one thick bed. Many of these thin limestones have a peculiar nodular-looking structure, which gives them an 'augen'-appearance that easily serves to distinguish them from any of the beds hitherto seen in the Rush coast-section. Interstratified with them are frequent partings and beds of shale or shaly limestone, seams of chert, and occasional thicker pure limestone-bands, not of the 'augen'-type, which, however, do not often exceed 7 or 8 inches in width.

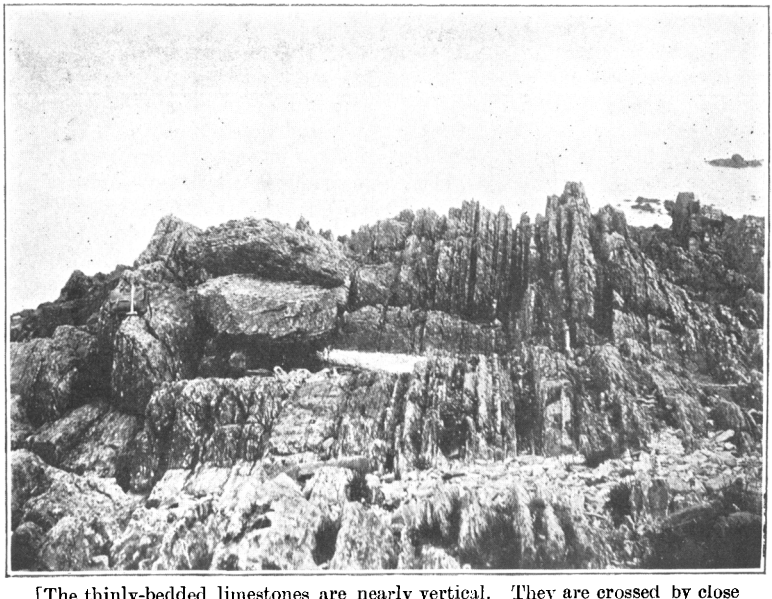
The stratigraphical arrangement of the beds is interesting. Their strike is a little to the north of east, their dip is often high, and the beds are folded and sometimes inverted. Where they are first seen at the Bathing-Place they emerge from the shore in several small folds, of which one anticline is well exposed. In the little cliff at the Bathing Place, there is a northerly dip at 80° and over, and two small thrusts are seen, intersecting at the foot of the cliff (fig. 9, p. 291). Some quite thin limestone-bands between the two thrusts are much contorted and shattered; and some imperfect cleavage in the shales is noticeable, the cleavage dipping to the south. The beds pass up, in a few feet, into highly-contorted, decomposed shaly beds with included seams of chert. It will be shown presently that these are decalcified beds. They form a syncline beyond which the limestones again emerge, dipping southward at an angle of 40° to 50°, while two or three adjacent beds form the long cliff-slope that bounds the south side

Fig. 9.—Cyathaxonia-*Beds at the Bathing-Place, north of Rush Bay.*



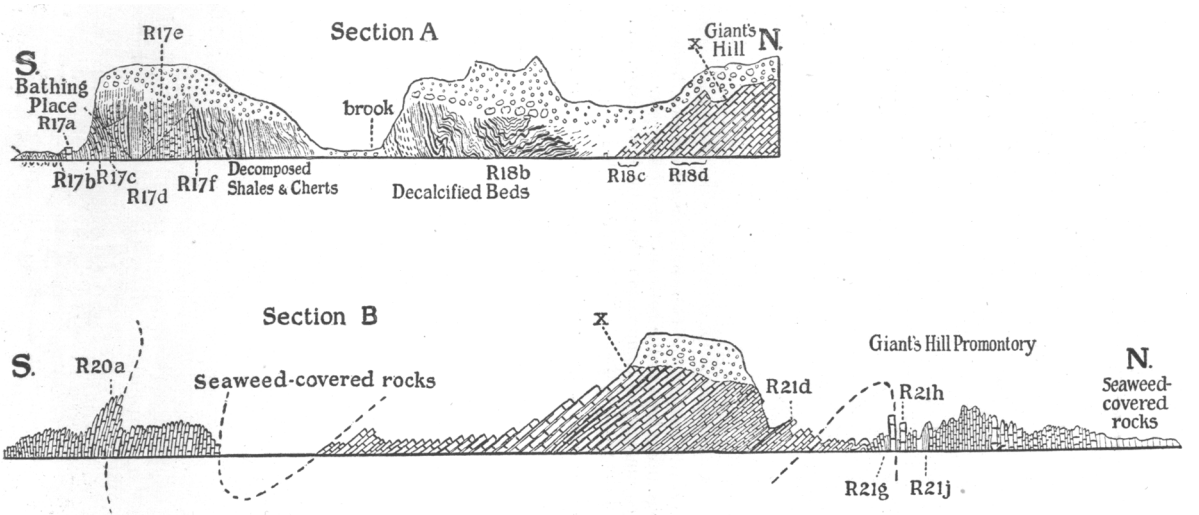
[The beds are nearly vertical, and two small thrusts are seen, hading in opposite directions. The beds at the bottom of the cliff appear to have undergone a greater amount of compression than the beds above, and thus have produced the effect of thrusts in the upper beds.]

Fig. 10.—Cyathaxonia-*Limestones on the coast at Giant's Hill, looking eastward.*



[The thinly-bedded limestones are nearly vertical. They are crossed by close parallel joints dipping southward, which appear to be of the nature of rough, imperfect cleavage-planes.]

Fig. 11.—*Parallel sections through the* Cyathaxonia-*Beds, between the Bathing-Place, north of Rush, and Brook's End, on the horizontal scale of 120 feet to the inch.*



[Section B is seaward of A, and the bed marked *x* in the latter corresponds with that which is similarly marked in the former.]

of Giant's Hill. Following these beds to the seaward face of Giant's Hill, another good section in the *Cyathaxonia*-Beds is exposed. The rocks are here arranged in an asymmetrical anticline, the northern slope of which as far as Brook's End is vertical, while the southern has a dip of only 35° to 45°; and in the core of the arch are several minor folds with a tendency to be overfolded or overthrust towards the north. The 'augen'-looking character of the thin limestones is well marked in many of the beds here.

Returning now to the Bathing-Place, we can walk at low tide to the rocks seaward of it, and make a traverse to the north parallel with the section in the cliff. The beds are somewhat overturned at the commencement, but the structure is practically a simple syncline of which the central beds are unexposed through the drifting-in of sand. We begin with a horizon that can be followed to the cliff, and we end with a horizon that can be traced into the cliff; but the intermediate beds of the syncline are very different in the two parallel sections. Seaward, the beds are of the ordinary character previously described, that is to say they are for the most part limestones; whereas all the limestones have disappeared from the beds of indubitably the same horizon in the cliff-section, where all that is left in lieu of the original rocks is a contorted, weathered, and ironstained mass of shale and chert, representing the insoluble residue of the beds after the removal of the calcareous matter. These decalcified beds have a thickness of apparently about 100 feet, which of course represents a much greater thickness of the original rocks. On each side of the syncline enclosing the decalcified material, the limestones are for some little distance rather rotten and partly decalcified, but the change to complete decalcification is more abrupt than would be expected.

The excavation of limestone by underground water, the 'piping' of chalk, and similar phenomena resulting in the local removal of limestone-beds, have of course long been known. The dwindling and disappearance of limestones by solution was discussed, from a theoretical standpoint, by Rutley in 1893[1]; and in 1903 Mr. C. T. Clough[2] described actual instances of their disappearance in High Teesdale, where the Great Limestone, 55 feet thick, is shown to have been often completely removed (especially along the outcrop) and replaced by 10 or 12 feet of soft siliceous clay ('famp'). I have myself seen further instances of limestone-solution along the Dublin coast nearer Loughshinny; and it is probable that this effect is commonly produced on a large scale in many parts of Ireland. Indeed, the origin of many of the great Irish lakes, and even of the gulfs and bays, has been held to be the result of chemical solution of Carboniferous Limestone.[3]

There are two small but interesting thrust-planes, in the black decomposed shales with cherts that form the southern margin of the decalcified beds described above. Their hade is very low, and

[1] Quart. Journ. Geol. Soc. vol. xlix (1893) p. 372.
[2] Geol. Mag. 1903, p. 259.
[3] E. Hull, 'Physical Geology & Geography of Ireland' 1878, pp. 198–209.

along them the beds have been pushed southward about 5 feet and 1 foot respectively, the upper thrust having the greater travel. These dislocations have evidently been produced since the decalcification, and they seem to be most easily explained as the effect of the movement of an ice-sheet in Glacial times.

These black shales, in which cleavage is sometimes still recognizable, are correlated by the officers of the Irish Geological Survey with the Black-Shale Series of Loughshinny, but they almost certainly belong to a lower horizon. At Loughshinny a band crowded with *Posidonomya Becheri* occurs in the limestones some 70 feet below the Loughshinny Black Shales; whereas here the uppermost limestones are in the *Cyathaxonia*-subzone below the zone of *P. Becheri*.

Dr. G. J. Hinde, F.R.S., has been good enough to examine three slices cut from the chert-bands in this locality; one from the fresh unaltered chert, one from the partly-decalcified beds, and one from the completely-decalcified area. He finds in them various foraminifera (*Endothyra*, *Nodosinella*, *Trochammina*, and *Valvulina?*), *Calcisphæra (?)*, sponge-spicules, etc. The specimen of decalcified chert is distinguished by an absence of calcareous material and foraminifera; and there are certain bodies in it which, although some of them may be cross-sections of sponge-spicules, have more the appearance of casts of simple forms of radiolaria. Dr. Hinde remarks that the chert-slices have a close resemblance to specimens in his possession from the River Hodder.

The fauna of the *Cyathaxonia*-Beds is tabulated in the faunal lists (p. 297); and from Dr. Vaughan's correlation it appears that, although these beds are represented in the South-Western Province of England and Wales, they correspond more closely, indeed precisely, with the limestones of Park Hill, Thorpe Cloud, etc. of the Midland Province of England.

(*g*) Curkeen-Hill Limestone.

Curkeen Hill does not lie on the coast, but is a locality inland, near an old quarry on the road from Rush to Skerries, near Loughshinny. A list of the fauna of its limestone-beds and their correlation are introduced here, because the beds occupy a gap in the Rush sequence; and there was a unique opportunity during the present year (1905) of collecting fossils from them, owing to the lowering of the road at the top of the hill in order to reduce the gradient. The limestone is a rock of a lighter grey colour than the limestones seen at Rush. The Geological Survey-map indicates that the horizon of this limestone lies below that of all the rocks of the Rush section, although Jukes expressed in the Survey-memoir (*op. cit.* p. 66) his reluctance to accept this view on stratigraphical grounds. That his objection was well founded is now proved by the result of the zonal examination of the fossils, which shows that the Curkeen-Hill Limestone is of Upper *Dibunophyllum*-age (D_2), though probably older than the *Cyathaxonia*-Beds of Rush.

IV. Summary of Conclusions. [C. A. M.]

The following is a summary of the most important points referred to in this paper.

(1) The Carboniferous rocks at Rush consist of about 2500 feet of slates, conglomerates, and limestones, which range from the Upper *Zaphrentis*-Zone to the Upper *Dibunophyllum*-Zone (*Cyathaxonia*-subzone).

(2) The Conglomerates belong to the *Syringothyris*-Zone, and indicate that the Mid-Avonian elevation and disturbance recently noted at Pendine and Weston-super-Mare extended into Ireland.

(3) There is a general upward succession of the beds from south to north, and the rocks have all been subject to severe earth-pressure acting from the south. Many of the beds are well cleaved, and the limestones have been thrown into many acute folds and are sometimes slightly overfolded.

(4) Among the *Cyathaxonia*-Beds local decalcification has caused the complete disappearance of a considerable thickness of limestones.

(5) The limestone of Curkeen Hill is of Upper *Dibunophyllum*-age, but probably of a lower horizon than the *Cyathaxonia*-Beds of Rush.

In conclusion, I wish to express my very great indebtedness to Dr. Vaughan for his ungrudging help in undertaking the examination and description of the fossils from these beds, and for contributing the following account of the correlation of the rocks at Rush; also to Dr. G. J. Hinde, Dr. Wheelton Hind, Dr. A. H. Foord, Dr. F. A. Bather, and Mr. R. Kidston, F.R.S., for assistance in determining certain of the fossils; and finally to Mr. C. Murray, B.A., of Dublin, for help in collecting the fossils.

V. Faunal Lists.[1] [A. V.]

The Slates (*Zaphrentis*-Beds).

R 1 b.	*Zaphrentis* cf. *Phillipsi*. *Productus* sp. (cf. *Pr. rugatus*).	*Phillipsia* sp.
R 4 a.	*Zaphrentis* cf. *Phillipsi*. *Productus* cf. *Martini (?)* *Orthothetes* cf. *crenistria* (cf. mut. Z_2). *Spirifer* cf. *clathratus (?)* Spiriferid (cf. *Syringothyris* cf. *laminosa*).	*Athyris* sp. (cf. *A. Royssii*, mut. β). *Camarotœchia* sp. (?) *Loxonema* sp. (fragment).[2] Fenestellid. Fistuliporid.
Near R 4 a.	*Zaphrentis* cf. *Phillipsi*. *Bellerophon* sp.[2]	
R 5 a.	*Zaphrentis* cf. *Phillipsi*.	

[1] In addition to the fossils mentioned in the following lists, fragments of crinoids occur in some abundance throughout the sequence.

[2] Determined by Dr. Wheelton Hind, F.G.S.

R 6 a.	*Zaphrentis* cf. *Phillipsi*. Bisulcate *Spirifer*.	Athyrid.
R 6 b.	*Zaphrentis* cf. *Phillipsi* (abundant). *Amplexi-Caninia*. *Chonetes* cf. *crassistria*. *Spirifer* cf. *cinctus*.	*Spirifer* sp. *Syringothyris* cf. *laminosa*. *Syringothyris* sp. *Athyris* cf. *glabristria*.

Dr. F. A. Bather, F.G.S., has kindly examined the crinoids obtained from this bed, and reports as follows:—

'The crinoids appear to be *Actinocrinus* and *Platycrinus*. One of the *Actinocrinus* seems to me to be *A. polydactylus*, Miller; and the *Platycrinus* from the same bed resembles a young *Pl. expansus*, M'Coy.'

R 7 d.	*Zaphrentis* cf. *Phillipsi*.	
R 7 e.	*Amplexi-Caninia*.	*Fenestella* (abundant).
R 8 a.	*Zaphrentis* cf. *Phillipsi* and variants. *Orthothetes* cf. *crenistria* (cf. mut. C), abundant. Spiriferid.	*Athyris* cf. *glabristria* (for form compare *A. planosulcata*). Monticuliporoid (with resemblance to *Favosites parasitica*).

THE CONGLOMERATES (*MICHELINIA* cf. *MEGASTOMA*-Beds).

R 9 e.	*Syringopora* cf. *ramulosa*.	*Michelinia (?)*
R 9 g.	Densiphylloid *Zaphrentis*.	
R 10 b.	Small *Chonetes* (see Note under § VI, p. 300).	*Orthothetes*. Seminuloid Athyrid.
R 10 c.	*Productus* cf. *concinnus* (or *Pr.* cf. *Martini*; specimen crushed). *Schizophoria resupinata*.	*Spirifer* cf. *striatus*. *Spirifer* sp. *Athyris* cf. *glabristria*. *Fenestella*.
	{Limestone-inclusion in R 10 g:—	
	Large semireticulate *Productus*. *Orthothetes*.	*Schizophoria (?)* *Athyris* cf. *expansa*. *Athyris* cf. *glabristria*.}
R 10 h.	*Syringopora* cf. *reticulata*.	
	{Limestone-inclusion in R 10 h:—	
	Productus cf. *concinnus*. *Productus* cf. *rugatus*.	*Seminula*-like Athyrid. *Phillipsia*.}
R 10 j.	Carcinophylloid *Clisiophyllum*.	
R 10 k.	*Syringopora* cf. *reticulata*.	
R 10 m.	*Syringopora* cf. *reticulata*. *Michelinia* cf. *megastoma*.	{R 10 m. (Loose block.) *Clisiophyllum* aff. *curkeenense*, sp. nov.}

Below R 11 a. *Glyphioceras* sp.[1]

[1] Determined by Dr. A. H. Foord, F.G.S.

R 11 a.	*Syringopora* cf. *reticulata*. *Michelinia* cf. *megastoma*. Densiphyllid. *Lithostrotion cyathophylloides*, sp. nov. Carcinophylloid *Clisiophyllum*.	*Chonetes* cf. *papilionacea*. *Spirifer* cf. *striatus*. Spiriferid (compare *Syringothyris* cf. *laminosa*). *Athyris* cf. *expansa*. *Athyris* cf. *glabristria (?)*
R 11 b.	*Syringopora* cf. *reticulata*. *Michelinia* cf. *megastoma*. *Amplexus* sp. *Densiphyllum*.	*Cyathophyllum* cf. *ϕ*. *Lithostrotion cyathophylloides*. Carcinophylloid *Clisiophyllum (?)* *Athyris* cf. *expansa*.
R 11 d.	*Lithostrotion cyathophylloides*, sp. nov.	
R 11 g.	*Syringopora* cf. *reticulata*. *Amplexus* sp. *Lithostrotion cyathophylloides*, sp. nov.	*Productus* cf. *concinnus*. *Chonetes* cf. *papilionacea*. *Spirifer* cf. *striatus*.
R 11 h.	*Amplexus* sp. *Lithostrotion cyathophylloides*, sp. nov.	*Productus* cf. *concinnus*. *Spirifer* sp. *? Syringothyris* cf. *laminosa*.
R 12 b.	*Productus* cf. *fimbriatus*. Semireticulate *Productus*. *Athyris* cf. *expansa (?)* Rhynchonellid.	} Very fragmentary.

{Precise horizon unknown, but certainly between R 9 e and R 12 b:—*Michelinia*, mutation towards *Beaumontia*.}

R 12 e. Land-plants (? ferns)—fragmentary. (Examined by Mr. R. Kidston, F.R.S.)

{Limestone-bed in Rush Harbour:—Pustulose *Productus* (cf. R 17 a).}

Carlyan Rocks.

R 14 a.	*Productus* cf. *semireticulatus*. *Chonetes* sp. (convex papilionacean).	Orthid. Seminuloid Athyrid (?)

Kate Rocks.

R 16 b.	*Chonetes* cf. *papilionacea (?)*	*Orthothetes* sp. (?)

Cyathaxonia-Zone.

R 17 a.	*Amplexi-Zaphrentis (?)* *Lonsdalia (?)* *Cyathaxonia rushiana*, sp. nov. *Productus concinnus*. *Productus scabriculo-costatus*. *Productus elegans* (= *Pr. punctato-fimbriatus*). *Productus fimbriato-pustulosus* (cf. Davidson, 'Monogr. Brit. Foss. Brachiopoda' Palæont. Soc. pt. v, 1861, pl. xlii, figs. 1 & 2).	*Productus margaritaceus*. *Productus corrugatus*. Papilionaceous *Chonetes*. Orthid (*Rhipidomella ?*). *Orthothetes* cf. *radialis*. *Spirifer bisulcatus* (two variants). *Spirifer triradialis*. *Straparollus* cf. *Dionysii*.[1] *Loxonema* sp., cf. *L. sulcatum*.[1]

[1] Determined by Dr. Wheelton Hind, F.G.S.

R 17 b.	*Lithostrotion* cf. *cyatho-phylloides*, sp. nov.	*Lithostrotion Phillipsi.* Campophyllid.
	{Seaward of R 17 c :— *Lithostrotion Phillipsi* (abundant). *Productus semireticulato-longispinus.*}	
R 17 c.	*Amplexi-Zaphrentis*, subgen. nov. *Lithostrotion Phillipsi.* *Schizophoria resupinata* (abundant fragments).	Bisulcate *Spirifer* (fragment). *Seminula* sp. *Straparollus* sp.[1] Echinid-plates.
R 17 d.	*Cyathaxonia rushiana*, sp. nov. *Productus* aff. *semireticulatus.* *Chonetes* sp. (convex papilionacean).	*Schizophoria resupinata.* Fenestellid.
R 17 e.	Bisulcate *Spirifer.*	*Glyphioceras truncatum.*[2]
R 17 f.	*Cladochonus* sp. (?) *Lithostrotion* sp. (probably =R 21 j specimen). *Cyathaxonia rushiana*, sp. nov. Aulophylloid *Clisiophyllum.* *Productus concinnus.* *Productus* aff. *scabriculus.* *Productus elegans.* *Productus pustuloso-fimbriatus* (cf. *Pr. Youngianus*). *Productus margaritaceus.* *Chonetes* sp. (convex papilionacean).	*Schizophoria resupinata.* *Leptæna* cf. *distorta.* *Orthothetes* cf. *radialis.* *Spirifer bisulcatus.* *Spirifer striatus* (cf. Curkeen Limestone). *Syringothyris subconica.* *Athyris glabristria* (convergent on *Martinia glabra*). *Camarophoria* aff. *isorhyncha* (cf. Curkeen Limestone). Fenestellid. *Phillipsia* sp. (abundant).
R 20 a (in chert) :—		
	Endothyra sp. *Nodosinella* sp. *Trochammina* sp.	*Calcisphæra (?)* Spines of echinoids. Spicules of sponges.
	(Determined by Dr. G. J. Hinde, F.R.S.)	
R 21 g.	*Zaphrentis* aff. *Enniskilleni.* Clisiophylloid *Lithostrotion* (convergent on *L. cyatho-phylloides*). *Cyathaxonia (?)* *Productus costato-semireticulatus.* *Productus elegans.*	*Productus hemisphericus.* *Chonetes* sp. (convex papilionacean). *Schizophoria resupinata.* *Syringothyris subconica.* Spiriferid (cf. *Martinia ovalis*) fragment.
R 21 h.	Cymatiophylloid Clisiophyllid.	
R 21 d.	*Cladochonus* cf. *bacillarius.* *Cyathophyllum* sp. *Amplexi-Zaphrentis* (variant convergent on *Zaphrentis* aff. *Enniskilleni*). Caninoid Clisiophyllid. *Densiphyllum.*	*Cyathaxonia rushiana*, sp. nov. *Cyathaxonia contorta*, sp. nov. Semireticulate *Productus.* *Spirifer bisulcatus.* *Syringothyris subconica.* *Athyris* cf. *expansa.* *Athyris planosulcata (?)*
R 21 j.	*Zaphrentis* aff. *Enniskilleni.* Clisiophylloid *Lithostrotion.* *Cyathaxonia rushiana*, sp. nov.	*Productus longispinus.* *Choneti-Productus (?)* *Schizophoria resupinata.*

[1] Determined by Dr. Wheelton Hind, F.G.S.
[2] Determined by Dr. A. H. Foord, F.G.S.

R 18 d. *Cyathaxonia rushiana*, sp. nov.

R 18 c. *Amplexi-Zaphrentis*, subgen. nov.
Cyathaxonia rushiana, sp. nov.
Cyathaxonia contorta, sp. nov.
Aulophylloid *Clisiophyllum*.
Productus costato-semireticulatus.
Productus aff. *scabriculus*.
Productus margaritaceus.
Productus cf. *corrugatus* (abundant fragments).
Chonetes sp. (convex papilionacean).
Orthothetes (?)
Euomphalus crotalostomus (?) [1]
In chert: *Endothyra* sp., *Valvulina (?)*, *Calcisphæra (?)*, Sponge-spicules. [2]

R 18 b. Athyrid (?)
(In chert) Radiolarians (?) Examined by Dr. G. J. Hinde, F.R.S.

CURKEEN LIMESTONE (correlated with the Upper *DIBUNOPHYLLUM*-Zone).

Lithostrotion cyathophylloides, mut. towards *Koninckophyllum*.
Clisiophyllum curkeenense, sp. nov.
Cyathaxonia contorta, sp. nov.
Productus concinnus and variant towards *Pr. pugilis*.
Productus scabriculo-costatus.
Productus corrugatus.
Productus fimbriato-pustulosus (cf. Davidson, 'Monogr. Brit. Foss. Brachiop.' Palæont. Soc. pt. v, 1861, pl. xlii, fig. 1, and cf. *Pr. ovalis*).
Productus aculeato-fimbriatus.
Chonetes sp. (convex papilionacean).
Schizophoria resupinata (abundant) and variant towards *Rhipidomella*.
Leptæna cf. *distorta*.
Derbya (?) cf. *senilis*.
Derbya anomala.
Spirifer striatus and variants.
Martinia glabra.
Reticularia lineata (?)
Athyris glabristria (convergent on *Martinia glabra*).
Pugnax acuminatus.
Camarotœchia (?) cf. *flexistria*.
Camarophoria aff. *isorhyncha*.
Dielasma aff. *hastata*.
Edmondia Lyellii.
Conocardium inflatum.
Bellerophon hiulcus.
Euomphalus pentangulatus.
Euomphalus latus. [1]
Platyschisma helicoides.
Straparollus Dionysii.
Naticopsis ampliata.
Loxonema supremum.
Orthoceras laterale.
Vestinautilus carinifer. [3]
Planetoceras globatum.

VI. ACCOUNT OF THE FAUNAL SUCCESSION AND CORRELATION. [A. V.]

1. Fauna of the '*Zaphrentis*-Beds'; (R 1 *b* to R 8 *a*).

(i) Corals:

The one feature of importance is the abundance of a small *Zaphrentis*, resembling *Z. Phillipsi*, Edwards & Haime. With the exception of a few specimens of an ill-preserved *Caninia*-like form, *Z.* cf. *Phillipsi* is the only coral found.

(ii) Brachiopods:

The specimens are few and fragmentary, and consequently the

[1] Determined by Dr. Wheelton Hind, F.G.S.
[2] Determined by Dr. G. J. Hinde, F.R.S.
[3] Determined by Dr. A. H. Foord, F.G.S.

following determinations are subject to a considerable error of identification.

Productus cf. *Martini ?* (Sow.).
Chonetes cf. *crassistria* (M'Coy).
Orthothetes crenistria (Phil.), cf. mut. Z_2 and mut. C.
Spirifer cf. *clathratus (?)* M'Coy.
Spirifer cf. *cinctus*, Keys., de Kon.
Syringothyris cf. *laminosa* (M'Coy) (Dav. *pars*).
Athyris sp. (cf. *A. Royssii*, mut. β).
Athyris cf. *glabristria* (Phil.), and variant towards form of *A. planosulcata* (Phil.).
Camarotœchia (?)

Correlation of the '*Zaphrentis*-Beds' with the Upper *Zaphrentis*-Zone of the Avonian of the South-Western Province.—This correlation rests upon the following facts common to the two developments:—

(1) The abundance of *Zaphrentis* cf. *Phillipsi;*
(2) The absence of *Cyathophyllum*, *Lithostrotion*, and Clisiophyllids;
(3) The absence or rarity of longitudinally-ribbed *Producti.*

The abundance of *Zaphrentis* would indicate the upper division of the *Zaphrentis*-Zone.

2. Fauna of the '*Michelinia* cf. *megastoma*-Beds'; (R 9 *e* to R 11 *h*).

[The typical characters are not, however, developed until R 10 *h*.]

(i) Corals:

Syringopora cf. *ramulosa*, Goldf.
Syringopora cf. *reticulata*, Goldf.
Michelinia cf. *megastoma* (Phil.).
Michelinia (mutation towards *Beaumontia*).
Amplexus sp.
Densiphyllid.
Lithostrotion cyathophylloides, sp. nov.
Cyathophyllum cf. ϕ, Vaughan.
Carcinophylloid Clisiophyllid.
Clisiophyllum aff. *curkeenense*, sp. nov. (a less-specialized variant).

The association of *Syringopora* cf. *reticulata*, *Michelinia* cf. *megastoma*, and *Lithostrotion cyathophylloides*, in abundance, forms a striking feature of this group of beds. Of these three corals, the two first-mentioned are confined to this zone, and the last of the three is only doubtfully represented in the *Cyathaxonia*-Beds.

(ii) Brachiopods (subject to a considerable error of identification):

Productus cf. *concinnus* (Sow.).
Productus cf. *fimbriatus.*
Small *Chonetes* (possibly young papilionacean).
Large *Chonetes* (convex papilionacean).
Schizophoria resupinata (Martin).
Orthothetes.
Spirifer cf. *striatus* (Martin).
Syringothyris cf. *laminosa ?* (M'Coy).
Athyris cf. *glabristria* (Phil.).
Athyris cf. *expansa* (Phil.).
Seminuloid Athyrid.

Correlation of the '*Megastoma*-Beds' with the *Syringothyris*- and Lower *Seminula*-Zones of the Avonian of the South-Western Province.—This correlation rests upon the following facts:—

(1) *Michelinia* cf. *megastoma* and *Syringopora* cf. *reticulata* are, in the South-Western Province, confined to C and S_1, of which zones they are characteristic.
(2) *Lithostrotion* is rare at the top of C, and becomes abundant at the base of S_1.

(3) Certain structural characters of the variant of *Clisiophyllum curkeenense* are paralleled in the early Clisiophyllids from C-S_1 of the South-Western Province.
(4) *Productus* cf. *concinnus* and *Athyris* cf. *expansa* are characteristic of C-S_1 in the South-Western Province.
(5) The entrance and abundance of convex papilionaceans is highly characteristic of C in the South-Western Province.
(6) The entrance of fimbriate *Producti*, a striate *Spirifer*, and of *Schizophoria* in its typical form.[1]

3. Fauna of the '*Cyathaxonia*-Beds'; (R 17, R 21, and R 18).

(i) Corals:

Cladochonus cf. *bacillarius*, M'Coy.
Amplexi-Zaphrentis, subgen. nov.
Zaphrentis aff. *Enniskilleni*.
Cyathophyllum sp.
Densiphyllum.
Lithostrotion Phillipsi, Edwards & Haime.
Clisiophylloid *Lithostrotion*.
Caninoid Clisiophyllid.
Campophyllid.
Cymatiophylloid Clisiophyllid.
Cyathaxonia rushiana, sp. nov.
Cyathaxonia contorta, sp. nov.
Aulophylloid *Clisiophyllum*.

Cyathaxonia rushiana is highly characteristic, and occurs throughout; it is, therefore, a very valuable index.

Cladochonus is also a striking fossil, but is apparently limited to a single bed (R 21 *d*).

Amplexi-Zaphrentis and *Zaphrentis* aff. *Enniskilleni* are not uncommon, and are important from the standpoints of evolution and correlation.

The Clisiophyllids are all of a Caninoid aspect.

(ii) Brachiopods:

Productus concinnus.
Productus semireticulatus (Martin), and variants towards *Pr. costatus*, Sow., and towards *Pr. longispinus*, Sow.
Productus longispinus, Sow.
Productus scabriculo-costatus.
Productus aff. *scabriculus* (Martin).
Productus fimbriato-pustulosus and variant towards *Pr. Youngianus*, Dav.
Productus elegans, M'Coy (= *Pr. punctato-fimbriatus*).
Productus margaritaceus, Phil.
Productus corrugatus, M'Coy.
Productus hemisphericus, Sow.
Choneti-Productus (?)
Chonetes (convex papilionacean).
Schizophoria resupinata (Martin).
Leptæna cf. *distorta*, J. Sow.
Orthothetes cf. *radialis* (Phil.).
Spirifer bisulcatus, Sow. and variants.
Spirifer triradialis, Phil.
Spirifer striatus (Martin).
Syringothyris subconica (Martin).
Athyris glabristria (Phil.) convergent on *Martinia glabra*.
Athyris cf. *expansa* (Phil.).
Athyris planosulcata ? (Phil.).
Seminula sp.
Camarophoria aff. *isorhyncha* (M'Coy).

[1] I have already pointed out, in Quart. Journ. Geol. Soc. vol. lxi (1905) p. 296, that the subzonal index of Z_2 in the Avonian sequence differs rather considerably from Martin's type of *Schizophoria resupinata*. Since this leads to confusion, I have decided to reject *Schizophoria resupinata*, mut. Z_2, as a subzonal index, and to replace it by *Zaphrentis* aff. *cornucopiæ*, which therefore becomes the index of Z_2. The typical *Schizophoria resupinata* is only found in the South-Western Province at the very base of C, and no specimens have, as yet, been recorded from any other horizon.

The foregoing determinations are subject to but a small error of identification.

Correlation of the '*Cyathaxonia*-Beds' with some part of the Upper *Dibunophyllum*-Zone of the Avonian of the South-Western Province.—For the purpose of correlation the facts may be marshalled thus:—

(i) As regards the Corals:—

(1) *Cyathaxonia* and *Cladochonus* are unknown in the South-Western Province.

(2) *Amplexi-Zaphrentis* and *Zaphrentis* aff. *Enniskilleni* abound in the upper D-beds of Oystermouth (Gower).

(3) The Clisiophyllids are comparatively scarce, and do not exhibit a very advanced type of structure, the Caninoid type being predominant. They cannot be actually matched from the South-Western Province, but would appear to have reached at least as advanced an evolutionary stage as our D_1 forms.

(ii) As regards the Brachiopods:—

(1) With the exception of the fimbriate and pustulose *Producti*, the convex-papilionaceous *Chonetes*, *Schizophoria resupinata*, *Athyris glabristria*, *Athyris* cf. *expansa*, and *Camarophoria* aff. *isorhyncha*, the brachiopod-fauna of the *Cyathaxonia*-Beds may be said to be completely diagnostic of the upper D-beds of the South-Western Province. The absence of the small *Chonetes* characteristic of e and the rarity of scabriculate *Producti* suggest, for the '*Cyathaxonia*-Beds,' a level at the top of D_2, below the very top of the Avonian of the South-Western Province.

(2) In the South-Western Province convex-papilionaceous *Chonetes* and *Athyris* cf. *expansa* do not transgress D_1.

Fimbriate and pustulose *Producti*, as well as *Athyris* cf. *glabristria*, have not been recorded above S_1.

Camarophoria isorhyncha (closely related, but not identical with the Rush form) is known only from the base of S_1.

Schizophoria resupinata is unknown above the base of C.

Syringothyris subconica is markedly convergent with *Cyrtina septosa*, a species which I have recently found in D_1 of Lydstep (Tenby). Regarded from an evolutionary standpoint, *S. subconica* could be derived from the gens of *S.* cf. *laminosa* by convergence with *Cyrtina septosa*; *Syringothyris* cf. *laminosa* is unknown above S_1.

The whole evidence, when proportionally weighed, seems to point with the greatest probability to the Upper *Dibunophyllum*-age of the '*Cyathaxonia*-Beds,' but the exact position which they occupy in that subzone is not as yet absolutely fixed.[1]

[1] It is very important to appreciate the fact that, during the Upper *Seminula*-period, the whole of the South-Western Province was subject to special conditions, and therefore exhibited a limited and peculiar fauna. In C and S_1 we can watch the birth and early mutation of all the gentes characteristic of Upper Avonian time; but, during the Lower *Seminula*-period, most of these groups were banished from the area, to continue their evolution elsewhere. It was not until the close of the *Dibunophyllum*-period that the normal conditions were restored, and the complete fauna returned. It is, therefore, impossible to study, from the evidence presented by the South-Western Province alone, the mutations to which each gens was subject during S_2 and D_1 time; and so too it is impossible to appreciate the exact time-value of the variations which can be observed in specimens from other areas.

Correlation of the '*Cyathaxonia*-Beds' with the uppermost beds of the Carboniferous Limestone on the south-western border of the Midland area.—During a short visit to Dr. Wheelton Hind, I had an opportunity of examining the uppermost beds of the Carboniferous Limestone, under his guidance, at a considerable number of localities lying on the margin of the Limestone-mass. The actual thickness examined cannot measure more than a few hundred feet, and exhibited two types of faunal assemblage:

(1) The rich brachiopod collecting-ground of Park Hill, Wetton, etc.

(2) The *Cyathaxonia*-Beds of Bradbourne.

(1) The Park-Hill fauna includes nearly all the brachiopods found in the '*Cyathaxonia*-Beds' of the Rush sequence, and quite a large number of forms are undoubtedly identical. Corals are scarce at Park Hill, etc., but I found the same Aulophylloid *Clisiophyllum* as that which occurs in R 17 *f* and R 18 *c*, near Wetton, and a Caninoid Clisiophyllid at Astbury, very similar to the specimen recorded from R 21 *d*.

(2) The Bradbourne Beds contain *Cyathaxonia rushiana* and *Amplexi-Zaphrentis*, even more abundantly than the Rush Beds. A further point of resemblance is the occurrence of *Cladochonus*, which Dr. Wheelton Hind pointed out to me as characterizing the Bradbourne level.

The relative position of these two types of strata in the Midlands is not, as yet, definitely settled; but, from an exposure near Kniveton, I am inclined to believe that the Bradbourne Beds immediately overlie the Park-Hill Series, and this conclusion Dr. Wheelton Hind thinks probable, from a large experience of exposures at other points of the area.

The correlation of the '*Cyathaxonia*-Beds' of Rush with the top of the Avonian in the Western Midlands is a fact beyond dispute, and so striking is the resemblance that it seems highly probable that the Rush and Western Midland beds belong to the same Province.

4. The Carlyan and Kate Rocks; (R 13 to R 16).

Fauna:—

Corals: None.

Brachiopods:

Convex-papilionaceous *Chonetes* (abundant).	*Orthothetes (?)*
Semireticulate *Productus*.	Seminuloid Athyrid.

Such an assemblage could occur at any level above Z in the South-Western Province.

5. The Curkeen Limestone.

(See special faunal list, p. 299.)

Analysis:—

(i) Corals:

Lithostrotion cyathophylloides, mutation towards *Koninckophyllum* (cf. *K.* θ of D_1, South-Western Province), and *Clisiophyllum curkeenense* both show marked development from the forms in the '*Megastoma*-Beds.'

Cyathaxonia contorta occurs also in the '*Cyathaxonia*-Beds.'

The Curkeen Limestone, therefore, should lie above the '*Megastoma*-Beds' and near the horizon of the '*Cyathaxonia*-Beds.' The stage of development suggests D_1.

(ii) Brachiopods:

The *Producti* indicate a somewhat lower level than the '*Cyathaxonia*-Beds.'

(1) Fimbriate or pustulose types are abundant.

(2) Highly-developed scabriculate types are absent, as also are the most specialized members of the semireticulate group (such as *Productus longispinus*) and the characteristic *Pr. margaritaceus*.

The *Chonetes* are convex papilionaceans.

Schizophoria resupinata is very abundant, and exhibits much individual variation of form: all its varieties could, however, be matched from Wetton, Astbury, etc.

Athyris glabristria also attains its maximum development, as it does at Kniveton in the Midland area.

Camarophoria aff. *isorhyncha* and *Leptæna* cf. *distorta*, together with the three species just cited, are common to the '*Cyathaxonia*-Beds' and the Curkeen Limestone.

The Spirifers belong to the striate group, and are apparently the descendants of the forms which make their first appearance in the '*Megastoma*-Beds' of the Rush sequence and in the *Syringothyris*-Zone of the South-Western Province.

Martinia glabra is abundant: in the South-Western Province we only know this form from D_2 (Oystermouth Limestone); it is common in the Park-Hill fauna.

Derbya anomala is identical with the Park-Hill form.

General conclusion:—The Curkeen Limestone cannot occur at any considerable distance from the '*Cyathaxonia*-Beds,' and, with great probability, lies immediately below them in some part of the Upper *Dibunophyllum*-Zone.

VII. Notes on the Genera and Species cited in the Faunal Lists. [A. V.]

If *P* be a generic name and *x* a specific name, *P* cf. *x* implies that, of all the named species of the genus *P*, *x* is that one which presents the closest resemblance to the form denoted by *P* cf. *x*.

By the use of this notation, it is further implied that there is no reason for believing that *Px* and *P* cf. *x* are links or appendages of the same chain of evolution (that is, *Px* and *P* cf. *x* are not members of the same gens).

P aff. *x* is any one of the links or appendages of the chain of evolution which contains the named species *Px* (that is, *Px* and *P* aff. *x* are members of the same gens).

Px cvgt. *Qy* implies convergence or assimilation between two contemporaneous species belonging to distinct genera.

Two cases of convergence are of common occurrence:—

(1) A general structural convergence which affects, in greater or less degree, all the genera of similar organisms living at the same time (for example, the general adoption of a Clisiophyllidan structure by the D_2 corals). This phenomenon may be termed a time-trait.

(2) A local convergence (or mimicry) by which the external form of two species belonging to distinct genera, but living in association, tends to become identical (for example, *Martinia glabra* and *Athyris glabristria* in the Curkeen Limestone).

A compound specific term, such as *Pyx*, indicates any form which varies from the type-species *Px* in the direction of the type-species *Py*; hence *Pyx* indicates an entire segment of a chain of evolution, extending from *Px* to *Py*, whereas *Px* and *Py* represent points only.

The employment of compound terms is, in many cases, more appropriate than the creation of new species when we are dealing with large divisions of time, such as are implied in zones; and especially is this the case when the whole of the segment represented by *Pyx* lies entirely within the zone.

BRACHIOPODS.

Semireticulate and scabriculate *Producti*.

Since I am now engaged upon the detailed study of this group, it will be sufficient here merely to schematize the lines of variation which are exhibited by the group in the Rush sequence.

In the appended scheme (fig. 12, p. 306), an unmodified specific name denotes the type of the original author.

Pustulose, fimbriate, and punctate *Producti*.

The *Producti* of this group are all ornamented with numerous, regularly-arranged, short, radial, procumbent spine-bases.

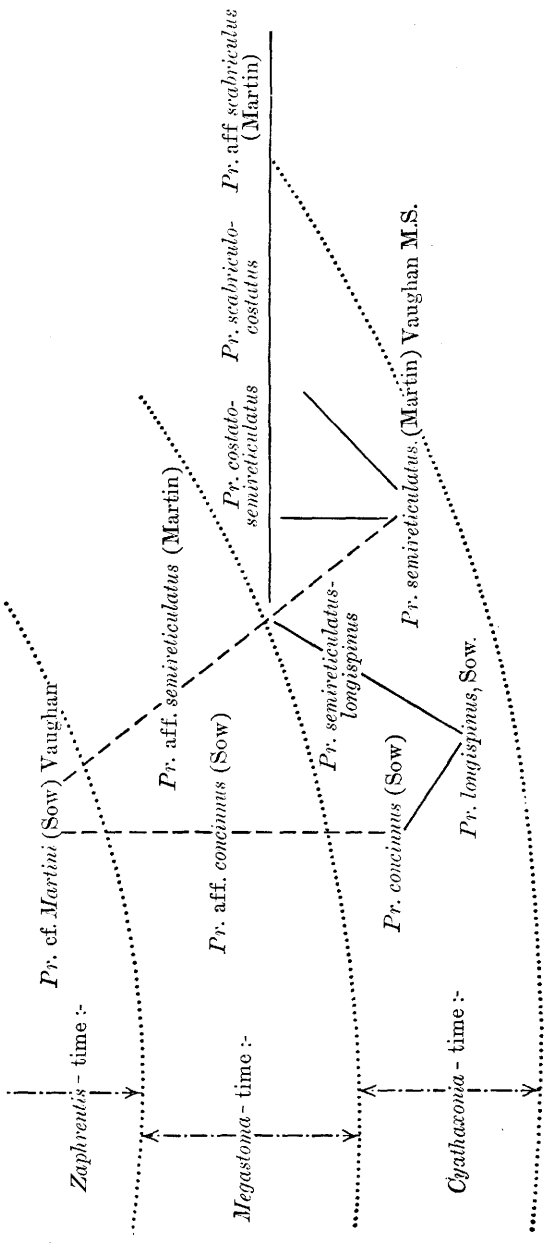


Fig. 12.—*Scheme of the lines of variation exhibited by the semireticulate and scabriculate* Producti *in the Rush sequence.* *(See p. 305.)*

The three fundamental types are:—

Productus pustulosus, Phil.,[1] *Pr. fimbriatus*, J. de C. Sow.,[2] and *Pr. punctatus* (Martin).[3] Martin's type of *Pr. punctatus* and Phillips's type of *Pr. pustulosus* agree in the form of the two valves, and in the possession of numerous concentric bands, separated by sharp grooves.

They differ completely in the nature and distribution of the spine-bases. In the type of *Pr. pustulosus*, the spine-bases are broad, well-spaced pustules arranged in concentric rows, each row ornamenting one of the concentric bands. In the type of *Pr. punctatus* the spine-bases are extremely numerous, small, and closely-packed, three to four concentric rows ornamenting each concentric band. (The spines which compose the uppermost row on each band are always larger than those of the lower rows.)

The type of *Pr. fimbriatus*, J. Sow., has the following characters:—

(*a*) Pedicle-valve.—Form elongate and continuously convex, with a short hinge-line and arched beak. A small number of broad concentric ridges, separated by broad concentric depressions. Broad, well-spaced spine-bases; a single concentric row of spines ornamenting each concentric ridge.

(*b*) The brachial valve is continuously concave.

Variation (in so far only as specimens cited in this paper are concerned):—

(1) Of *Pr. pustulosus*, in a direction diverging from the fimbriate and punctate groups.—Here is included *Pr. pyxidiformis*, de Kon.,[4] the type of which exhibits irregular concentric wrinkles, feebly separated by irregular concentric ruts. Pyxidiform variants of *Pr. pustulosus* are not uncommon in the *Cyathaxonia*-Beds of the Rush sequence and in the Curkeen Limestone. They are intermediate between *Pr. pustulosus* and *Pr. pyxidiformis*, the concentric banding being irregular, but the concentric grooves distinct.

(2) Of *Pr. pustulosus*, towards *Pr. fimbriatus*.—All such variants may be included under the term *Pr. fimbriato-pustulosus*. Here is included *Pr. ovalis*, Phil.,[5] the type of which has an elongate fimbriate form (flattened over the median area of the pedicle-valve); concentric grooves are very indistinct, and the spine-bases narrow. One of the forms from the Curkeen Limestone approaches very close to *Pr. ovalis*, differing only in the more marked separation of the concentric bands.

(3) Of *Pr. fimbriatus*, towards *Pr. punctatus* (= *Pr. punctato-fimbriatus*).—Here is included *Pr. elegans*, M'Coy,[6] the type of which is, in all respects of form and banding, a pure fimbriate

[1] 'Geology of Yorkshire' vol. ii (1836) pl. vii, fig. 15.
[2] 'Min. Conch.' vol. v (1825) pl. cccclix, fig. 1.
[3] 'Petrificata Derbiensia' 1809, pl. xxxvii, fig. 6.
[4] 'Monographie du Genre *Productus*,' Recherches sur les Animaux fossiles, pt. i (1847) pl. xvi, fig. 2.
[5] 'Geology of Yorkshire' vol. ii (1836) pl. viii, fig. 14.
[6] 'British Palæozoic Fossils' 1855, pl. iii H, fig. 4.

Productus, but the spine-ornament is exactly that of *Pr. punctatus*. This group is represented in the *Cyathaxonia*-Beds by a common form which appears to be identical with *Pr. elegans*.

In the Upper *Dibunophyllum*-Zone of the South-Western Province, a closely-similar, but larger, form is equally characteristic of the uppermost Avonian.

The specimen figured by Martin under *Pr. punctatus*,[1] as well as Phillips's figure of *Pr. fimbriatus*,[2] must be described as examples of *Pr. punctato-fimbriatus*, intermediate between *Pr. fimbriatus* and *Pr. elegans*.

A single specimen of a very peculiar fimbriate *Productus* was found by Dr. Matley just above the *Megastoma*-Beds.

The form and concentric banding are exactly those of *Pr. fimbriatus*, but the spine-bases are few, scattered, and usually erect. The relationship of such a form is very obscure, but probably it represents a link between the fimbriate and the aculeate *Producti*. The specimen is figured under the name *Productus* cf. *fimbriatus*, Pl. XXX, fig. 6.

PRODUCTUS MARGARITACEUS, Phil.

This *Productus* is highly characteristic of the *Cyathaxonia*-Beds, and it occurs at the same level, both in the South-Western Province and in the Midland area.

PRODUCTUS CORRUGATUS, M'Coy.

Specimens which appear to be identical with M'Coy's type[3] occur in the Curkeen Limestone and in the *Cyathaxonia*-Beds of the Rush sequence. The same form occurs in the Upper *Dibunophyllum*-Zone of the South-Western Province.

Chonetes.

Convex papilionaceous CHONETES.

The fragmentary nature of the specimens which have been collected from the Rush sequence forbids any more definite determination. This circumstance is much to be regretted, since, with the valuable help of Mr. T. F. Sibly, I have been carefully studying the mutation of this group, from early *Syringothyris*-time up to its acme of development in the Lower *Dibunophyllum*-Zone. The investigation depends upon the patient accumulation of specimens showing the internal characters. The material that we have already collected indicates the gradual change, from Orthothetoid convergence in Lower *Syringothyris*-time to the most pronounced Productoid convergence in Lower *Dibunophyllum*-time, as exhibited in *Producti-Chonetes* (=*Daviesiella*, Waagen) aff. *comoides*[4] of the South-Western Province.

[1] 'Petrificata Derbiensia' 1809, pl. xxxvii, figs. 7 & 8.
[2] 'Geology of Yorkshire' vol. ii (1836) pl. viii, figs. 11 & 12.
[3] 'Synopsis Carb. Limest. Foss. of Ireland' 1844 pl. xx, fig. 13.
[4] A. Vaughan, Quart. Journ. Geol. Soc. vol. lxi (1905) p. 295.

SCHIZOPHORIA RESUPINATA (Martin).

This gens occurs rarely in the *Megastoma*-Beds, but abundantly in the *Cyathaxonia*-Beds and in the Curkeen Limestone.

In the upper beds, the gens strikingly exhibits that exaggeration of characters which so frequently indicates approaching extinction. Great size and massive test, periodicity of ribbing accompanied by the development of prominent spines, numerous strongly-marked growth-lines producing conspicuous concentric ornament, deep sulcation of the brachial valve, and coarse longitudinal grooving (as in the Choneti-Productids of the same period), are among the most striking of the external characters. As regards internal characters, the muscular scars are deeply impressed and of large size; the cast exhibits strong, sharp, longitudinal ridges and a coarsely-punctate margin.

In the South-Western Province, as already noticed, no typical specimens of *Schizophoria resupinata* have yet been found in the Upper Avonian; the Lower *Syringothyris*-Zone is the only level at which typical examples are abundant. The early variant which characterizes Z_2 of that area is distinguished from the type-species by its small size and non-sulcate globose form.

On the other hand, every variation exhibited by the gens in the *Cyathaxonia*-Beds of Rush and in the Curkeen Limestone could be matched in specimens from the Wetton and Park-Hill Beds of the Midlands.

SCHIZOPHORIA[1] sp.

In the Curkeen Limestone, and associated with *Schizophoria resupinata*, occurs a small Orthid, which has a globose brachial valve and a flattened pedicle-valve. The hinge-line is short, as in a *Rhipidomella*, and the ribbing is of the type characteristic of that genus.

A closely-similar form occurs in the uppermost Avonian of Ragwen Point, near Tenby.

ORTHOTHETES (DERBYA) SENILIS (Phil.), var. (?) ANOMALA (J. Sow., *pars*).

Compare *Derbya ruginosa*, Hall.

Specimens are not uncommon in the Curkeen Limestone which have the characteristic billowy contortion; when sectioned, the pedicle-valve exhibits the strong mesial septum which is diagnostic of Waagen's genus *Derbya*.

Exactly-similar specimens are common at Park Hill (Midland area). At the base of D_1, in the South-Western Province, a

[1] This shell might equally well be termed a *Rhipidomella*. It is very doubtful whether, in the Carboniferous rocks, the distinction of *Rhipidomella* from *Schizophoria* can be considered to have generic value. There are certainly a large number of shells which can only be assigned to either genus, rather than the other, by unduly weighing one or other of the differences that are to be seen in the typical forms of *Schizophoria resupinata* and *Rhipidomella Michelini*.

transverse *Derbya* occurs somewhat abundantly; it has strong concentric ruts, but never exhibits the remarkable contortion of *Derbya anomala*.

Leptæna cf. distorta, J. Sow.

The dependent margin of the pedicle-valve is practically smooth, narrow, and deeply sinuated. The double-valved shell is biconvex, since the margin scarcely projects below the brachial valve.

This form occurs rarely in D_2 of the South-Western Province.

Spirifers.

Gens of Spirifer bisulcatus, Sow.

Figs. 13 & 14 in pl. vi, Davidson,[1] represent very closely the commonest type found in the *Cyathaxonia*-Beds of the Rush sequence. The flank-ribs, however, increase very markedly in strength as they approach the fold or sinus, after the pattern of *Sp. grandicostatus*, M'Coy.

The same form occurs abundantly in D_2 of Gower (South-Western Province).

Gens of Spirifer striatus (Martin).

Without undertaking the much-needed revision of the striate Spirifers, it is necessary to enumerate the most obvious of the characters exhibited by Martin's type-figure.

Broad, rectangular area, forming the widest part of the shell. Small, sharp, bicrested beak, recurved like a hook over the top line of the area. Both valves completely and sharply ribbed; the ribs are very numerous, and arranged in pairs or groups, radiating from the umbo of each valve; the ribbing on fold and sinus is on the same pattern as that of the flanks; the margin of the fold is non-truncate.

The Spirifers figured in Davidson, *op. cit.* pl. ii, and pl. iii, figs. 2, 4, 5, are probably all members of this gens; I should also include here such forms as pl. iv, fig. 4, and pl. vii, figs. 8 & 9.[2] *Spirifer planicosta*, M'Coy, should, I think, be excluded from this gens, and yet not included in the gens of *Sp. trigonalis*.

The predominant form in the Curkeen Limestone is very similar to the forms illustrated in Davidson, *op. cit.* pl. ii, fig. 17, and in pl. iii, fig. 5.

A well-marked variant, which resembles Davidson, *op. cit.* pl. vii, fig. 8, and pl. iv, fig. 4, is remarkable for its few very coarse and angular ribs, which split into groups of shorter ones as they traverse the valves. The same variant occurs in D_2 of the South-Western Province, and is there also associated with a normal member of the gens.

[1] 'Monogr. Brit. Foss. Brachiop.' (Palæont. Soc.) pt. v, 1858–63.

[2] The inclusion of a particular form in a certain gens must be decided by the constancy of its association (or time-sequence) with a recognized member of the gens, and not by the possession of one or more striking characters which may have been artificially set out as an exclusive test of membership.

SYRINGOTHYRIS SUBCONICA (Martin). (Pl. XXX, fig. 7.)

Characters of the pedicle-valve.—Form pyramidal. The area is a plane-triangle; the beak marks the apex of the area, but does not curve over it; deep angular sulcus, without ribs; the flanks are ornamented by seven or eight sharp, perfectly-radial ribs, which have a strong laminose concentric ornament.

This shell is a characteristic fossil in the *Cyathaxonia*-Beds of the Rush sequence, and is apparently not uncommon. The specimens from Rush appear to agree exactly with Martin's type-figure.[1]

A similar form (which, however, differs in the depression of the mesial fold) is figured by Davidson[2] from Wetton, and, judging from the numerous specimens in Dr. Wheelton Hind's collection, the form is common at Castleton.

In the South-Western Province only two specimens of a *Syringothyris* have yet been discovered in the top beds, and these must both be named *Syringothyris* cf. *cuspidata*.

Syringothyris cf. *laminosa* (Z_2 to S_1) differs markedly in its regularly-concave area (it has consequently a strongly *Spiriferina*-like aspect).

MARTINIA GLABRA (Martin).

This is an abundant fossil in the Curkeen Limestone. The predominant form is more transverse than Martin's type-figure (*op. supra cit.* pl. xlviii, figs. 9 & 10), and agrees more closely with the form figured by Davidson (*op. supra cit.* pt. v, pl. xi, fig. 3).

In the South-Western Province, *Martinia glabra* is only found in D_2, where it is locally very abundant (Oystermouth Beds, Gower); it is also very common in the uppermost Avonian of the Midland area.

There is, in the Curkeen Limestone, a very striking convergence between *Athyris glabristria* and *Martinia glabra*, both of which are extremely abundant there. They both possess the same contour and general convexity; the same broad, gentle, mesial swelling and shallow mesial depression; and the same broad and rounded beak-region. The widely-distinct generic characters can, however, always be made out by careful examination.

The test of the *Athyris* is completely fibrous, and has a 'matt' surface; that of the *Martinia* has a translucent lustre, due to the character of the minutely-punctured outermost layer.

When the beak is completely exposed, the *Martinia* has a triangular area and a short, straight hinge-line; the *Athyris* has no area, and the hinge-line is broadly angled.

If the test be removed from the rostral region, the *Martinia* is seen to have no dental plates; but the cast is marked by several very strong, sharp, radiating ridges, which stand up like septa. The

[1] 'Petrificata Derbiensia' 1809, pl. xlvii, figs. 6, 7, & 8.

[2] 'Monogr. Brit. Foss. Brachiop.' (Palæont. Soc.) Appendix, 1863, pl. lii. fig. 4.

Athyris has very strong, slightly-diverging dental plates, and the radiating ridges on the cast resemble low ribs.

ATHYRIS GLABRISTRIA, A. EXPANSA, and A. PLANOSULCATA.

I have recorded *Athyris glabristria* from various levels throughout the Rush sequence.

Athyris expansa is common in the *Megastoma*-Beds, and a single specimen is recorded from the *Cyathaxonia*-Beds.

Our knowledge of *Athyris* is, unfortunately, very incomplete, owing to the rarity with which specimens exhibit unweathered expansions. The distinction between a sheet-expansion—built up of tubular ribs webbed together, as in *Actinoconchus*, or the group of *Athyris planosulcata*, Phil., and a fringed expansion—in which the free margin of the expansion is composed of completely-detached, flattened, tubular spines, as in *Cliothyris*, or the group of *Athyris pectinifera* (Sow.), has been found to be of little assistance in the determination of specimens such as are usually met with in stratigraphical work. Specimens showing expansions are only to be found on weathered surfaces, and the continued weathering of a sheet-expansion removes the web faster than the thickened rib, thus producing a fringed margin. Unless I have been extremely unfortunate, this is the common case with specimens of *Athyris planosulcata*. The fringed Athyrids from the South-Western Province have been very carefully examined by Mr. T. F. Sibly and myself, and we have arrived at the definite conclusion that, with the probable exception of *A.* cf. *pectinifera* from D_2 of Gower, the detached spines never extend to the suture-line of the expansion, but they always spring from a more or less narrow basal lamella. Again, one part of the shell may appear to have fringed expansions, whereas the expansions in another part may be lamellæ, without any sign of fringe.

On the other hand, *Seminula* is usually separated with ease, by the absence of any trace of expansion and the terebratuliform lines of growth.

For these reasons, '*Athyris*' is here employed to cover all those Athyrids the expansions of which are either actually fringed, or may become so by weathering. It follows that 'species'-distinction becomes little more than form-denotation; the species-groups thus made are, therefore, in the nature of 'circuli,' and are, from a stratigraphical point of view, of little value.

The terms are here employed in the following sense:—

Athyris = Athyrids which exhibit fringes (either original or produced by weathering).

A. glabristria, Phil., has a gibbous, transverse form, with a broad mesial swelling and shallow depression; the beak is thick, with rounded slopes. The accentuation of the mesial swelling into a strong fold, standing out from the flanks, is, apparently, in the South-Western Province, distinctive of the Z_2 forms.

A. expansa, Phil., has a flattened, very transverse form with almost uniplanar valve-intersection and a non-prominent beak.

In the South-Western Province this form is very abundant, and characteristic of C and S_1.[1]

A. planosulcata, Phil., has a circular and uniformly-convex form, with a small pointed beak and uniplanar valve-intersection. The typical form is abundant only in the highest beds of the Avonian.

CAMAROPHORIA aff. ISORHYNCHA (M'Coy).

This fossil occurs, both in the Curkeen Limestone and in the *Cyathaxonia*-Beds of the Rush sequence. It differs from the form recorded by Mr. Sibly from S_1 of the Weston area,[2] in having more numerous ribs (which have a less outward sweep), and in the more restricted lateral lunules. It differs from M'Coy's type[3] in being much more compressed in thickness.

CAMAROTŒCHIA (?) aff. FLEXISTRIA (Phil.).

A single specimen from the Curkeen Limestone has its fold scarcely differentiated, and the fold-ribs not appreciably larger than those on the flanks.

CORALS.

SYRINGOPORA cf. RETICULATA, Goldf. (Pl. XXIX, fig. 1.)

The tubes are in parallel grouping, and, in a vertical section, at about the diameter of a tube apart. The connecting-tubes are short, and occur at points of approximation.

In a chance horizontal section, the number of actually-connected rings is relatively small, but the more closely-approximated pairs indicate the presence of a connector within a short distance of the plane of section.

In the Rush sequence this *Syringopora* is common in, and characteristic of, the *Megastoma*-Beds.

In the South-Western Province a very similar form occurs somewhat commonly in the *Syringothyris* and Lower *Seminula*-Zones, with which the *Megastoma*-Beds are here correlated. I know, however, a practically-identical *Syringopora* from the Main Limestone of Durham, a level which, judged by the associated fauna, is unquestionably of *Dibunophyllum*-age.[4]

In my account of the Bristol sequence[5] I have pointed out that the 'species' of *Syringopora* are of the nature of circuli; consequently a correlation of two levels in distant localities, based upon the similarity of the dominant Syringoporids, is partly valueless. On the other hand, in the examination of a single area, particular forms of *Syringopora* may be of great value.

Stated broadly, dimensional variation is a function of environment, whereas the degree of structural complexity is dependent on the earlier history of the gens, and is, consequently, a function of the time.

[1] T. F. Sibly, Quart. Journ. Geol. Soc. vol. lxi (1905) pp. 556, 557.
[2] *Ibid.* p. 557.
[3] 'Synopsis Carb. Limest. Foss. of Ireland' 1844, pl. xviii, fig. 8.
[4] Specimens from Durham have been kindly submitted to me for examination by Mr. J. T. Stobbs, F.G.S.
[5] Quart. Journ. Geol. Soc. vol. lxi (1905) p. 267.

ZAPHRENTIS cf. PHILLIPSI, Edwards & Haime.

See Vaughan, Quart. Journ. Geol. Soc. vol. lxi (1905) p. 269 & pl. xxii, figs. 2–2*e*.

The points of resemblance with *Zaphrentis* aff. *Phillipsi*, which characterizes Z in the South-Western Province, are :—

(1) External form and dimensions.
(2) As seen in a horizontal section :—
The spacing and number of the primary septa.
The rudimentary development of secondary septa.
The strong fossula, occupied by a long fossular septum.
The antifossular group of septa, bounded below by the elongation and union of the two extreme septa, and marked off from the fossular group by rudimentary lateral septal breaks.

The differences, are, however, strongly marked in the following characters of the Rush *Zaphrentis* :—

The septa composing the fossular groups are directed towards the centre, and not towards the walls of the fossula ; the fossula is, consequently, bounded by a single septum on each side, and is narrowly rectangular in section.

The middle of a horizontal section exhibits concurrent septa, whereas, in the *Zaphrentis* of the South-Western Province, the inner ends of the septa are merged into a dense central disc, formed by the intersection of the plane of section with one of the tabulæ.

In these differences *Zaphrentis* cf. *Phillipsi* makes an approach towards *Z.* aff. *Enniskilleni* (see p. 315), but the latter exhibits the following distinctive characters :—

(1) The tendency of the antifossular septa to fall short of the centre ;
(2) The fossula lies on the concave side of the coral, whereas, in *Z.* cf. *Phillipsi*, it is, apparently, always on the convex side ;
(3) The absence of a long fossular septum ; and
(4) The larger dimensions.

Two rather striking peculiarities are commonly exhibited by variants of the Rush *Zaphrentis* :—

(1) A marked development of an antifossular break, which strongly resembles the fossular break.

This character is also exhibited, though less commonly, in the *Zaphrentis* of the South-Western Province (see pl. xxii, fig. 2 *c*, *op. supra cit.*).

(2) The frequent development of an axial tube caused by the wrapping-round of the septa.

In this character there is a distinct approximation towards *Z. Bowerbanki*, Edwards & Haime, but the Rush coral is always separated by its short conical form, and by the fact that the antifossular septum does not extend into the axial tube (see fig. 13).

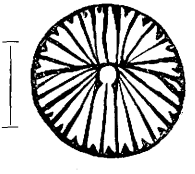


Fig. 13.—Zaphrentis *cf.* Phillipsi, *E. & H.*, *variant towards* Z. Bowerbanki, *E. & H.*, *showing the cross-section of the axial tube. From the* Zaphrentis - *Beds of Rush.*

More information is required as to the tabulæ of the Rush *Zaphrentis*, but this can only be obtained from good vertical sections.

Range.—The *Zaphrentis*-Beds only.

ZAPHRENTIS aff. ENNISKILLENI, Edwards & Haime. (Pl. XXIX, fig. 2.)

This gens includes a large number of closely-related forms which occur abundantly in the uppermost Avonian, and are diagnostic of that level.

The form is always conical and usually cornute.

The septa are strongly separated into three groups, namely, two fossular groups and one antifossular group. The fossula is extremely-well developed, and the lateral breaks are usually very strong. The tabulæ are, however, Amplexoid; the fossular septum is either absent or very short.

To this gens may be referred the corals figured by James Thomson in his pl. vi, figs. 4 & 10.[1]

Specimens are common in the *Cyathaxonia*-Beds of Rush, and at the same level at Bradbourne (Derbyshire). In the South-Western Province the gens is equally prolific in the uppermost Avonian of Gower.[2]

AMPLEXI-ZAPHRENTIS (subgenus nov.). (Pl. XXIX, fig. 7.)

Thomson, Proc. Phil. Soc. Glasgow, vol. xiv (1882–83) pl. vi. figs. 3, 9, & 13.

Form.—Conical, straight or curved.

Septal characters exhibited in a horizontal section.—The septal grouping is remarkably different at different stages of growth in the same individual:

(1) In the early stage. The septa are few in number and so closely approximated that the interspaces are extremely narrow; they are attached to the thick wall by very broad bases, and taper gradually towards the centre without bending.

The symmetry is strongly bilateral, the axis of symmetry being defined by two collinear septa which are respectively the longest and shortest of the septal series.

(2) In the intermediate stage. Many of the septa become shorter; broad tabulæ are developed; and a fossula is marked out, both by a break in the septal series, and by a shallow depression of each tabula.

In this stage two lateral and opposite septa often stretch across the corallum to meet in the centre, and separate an antifossular group of short septa from the two lateral groups on either side of the fossula. At the same time, broad lateral gaps may be developed in the septal sequence. Fig. 7 (Pl. XXIX) illustrates a variant of this description, and a comparison of the figure with fig. 2 of the same plate will show how deceptive is the convergence between this stage of *Amplexi-Zaphrentis* and the group of *Zaphrentis* aff. *Enniskilleni*, notwithstanding the fact that the early and late stages of the two groups are entirely distinct. Thomson's fig. 3, above cited, appears to be a typical example of the intermediate stage of an *Amplexi-Zaphrentis*.

(3) In the late stage. The septa all become short; flat tabulæ extend completely across the corallum, but bend down near the wall. The fossula is a

[1] 'Corals of the Carboniferous System of Scotland' Proc. Phil. Soc. Glasgow, vol. xiv (1882–83).

[2] I am at present engaged on the detailed study of these specimens, and consequently defer a more exhaustive account of the relationships of the gens.

broad shallow depression in each tabula, and is occupied by one or more short septa. Figs. 9 & 13 of Thomson, above cited, illustrate this stage.

(4) In the latest stage the outer wall partly splits, and the interspace is broadly vesicular, thus simulating a *Caninia*.

This subgenus occurs in the *Cyathaxonia*-Beds of Rush and Bradbourne; it is also found in the uppermost beds of the Avonian throughout the South-Western Province, where it is especially common in D_2 and ϵ of Oystermouth (Gower).[1]

CYATHAXONIA RUSHIANA, sp. nov. (Pl. XXIX, figs. 3, 3 *a*, & 3 *b*.)

Compare *Cyathaxonia cornu*, Mich., M'Coy ('Brit. Palæoz. Foss.' 1855, p. 109).

Form.—An elongated narrow cylinder, starting as a short curved cone.

Calyx.—Boundary a circle, with its plane perpendicular to the axis; rim sharp; from the middle of the calyx-floor projects a strong 'columella.' This 'columella' is a complex structure, consisting essentially of a thick tube surrounding a stout columellarian lath, the interspace being completely filled up.

Horizontal section.—Central area: oval and completely filled up, but the enclosing ring well-marked.

Septa: regular, radial, and well-spaced; 20 to 25 in number; all the septa are bilamellar, and, in the greater number, the lamellæ are separated near the periphery. The septal break is marked out by a unique thin septum, collinear with the columellarian lath.

This species is common at Rush in the *Cyathaxonia*-Beds, to which zone it is confined. The same species is abundant at Bradbourne (Derbyshire) at the same level.

So closely does M'Coy's description of *Cyathaxonia cornu* apply to the forms here included, that a new specific name might seem unwarranted; the reasons for its creation are as follows:—

(1) The axis of *C. cornu* is merely described by M'Coy as 'solid,' whereas the axis of all specimens of *C. rushiana* exhibits a very characteristic tubular structure.

(2) *Cyathaxonia cornu* is insufficiently defined by Michelin, and the identity of *C. cornu*, as a species, rests upon its interpretation by Edwards & Haime.[2] The description given by these authors does not suggest the characters of *C. rushiana*.

[1] I have carefully examined the specimens from Gower, and have had several sections cut from the same individuals, in order to observe the stages of growth; the above description of *Amplexi-Zaphrentis* is founded on the results of this examination. More study is, however, required to determine the relationship of the Upper Avonian forms with certain corals which occur in γ and C_1 of the South-Western Province and also with the '*Amplexi-Caninia*' which occurs in the *Zaphrentis*-Beds of Rush. The full description and illustration of this subgenus is consequently deferred.

[2] 'Monogr. des Polypiers Foss. des Terr. Paléoz.' 1851, p. 320 (Archives Mus. Hist. Nat. vol. v).

(3) The type-specimen figured by Michelin[1] was derived from Tournai, and therefore, presumably, from the Lower Avonian; all our specimens came from the top of the Upper Avonian.[2]

CYATHAXONIA CONTORTA, sp. nov. (Pl. XXIX, figs. 4 & 4 *a*.)

Form: short, conical, cornute.

Epitheca: strongly annulated and indistinctly costate.

Calyx: boundary a circle, perpendicular to the axis; rim sharp; inner slope radiated by a single series of equal, well-spaced septa; from the middle of the floor projects the very prominent, tall, laterally-compressed columella, the sides of which are roughened by vertical ridges.

Horizontal section.—Septa 30 to 40 in number, thick, simple, and bent. A distinct septal break is occupied by a short septum. All the septa are attached to the thick wall by an enlarged base.

The central area has an irregular, heart-shaped boundary, which is strongly thickened; within this bounding ring is the cross-section of the columella, finely serrated on its sides, the interspace being occupied by vesicles.

The interseptal spaces show a very few tabular intersections, the tabulæ having a very high slope.

Occurrence.—In the *Cyathaxonia*-Beds, where it is less abundant than the associated *C. rushiana*.

Relationship.—*C. contorta* resembles *C. rushiana* only in its central area. The septa differ markedly: in *C. contorta* they are single, bent, and numerous; in *C. rushiana* they are few in number, paired, and straight. In *C. contorta* the interseptal spaces are traversed by sparse tabulæ; in *C. rushiana* there are apparently neither tabulæ nor vesicles. The form of *C. contorta* is a

[1] 'Icon. Zooph.' 1840–47, p. 258 & pl. lix, fig. 9.

[2] M'Coy, however, states (*loc. cit.*) that he compared *Cyathaxonia cornu*, M'Coy, with specimens from Tournai, and found the 'coincidence exact.'

Mr. A. L. Leach, who has collected very carefully from the Carboniferous Limestone of the Tenby district, has very kindly allowed me to examine two specimens of a *Cyathaxonia* which he has discovered in the Lower Avonian of that locality.

In both specimens the calyx is well exposed, and exhibits a prominent columella which is apparently solid.

The septa, as seen in the calyx, are simple and alternate. The larger septa extend to the columella, the shorter project a very short distance from the wall. (It is unfortunate that the friable nature of the specimens forbids any attempt to obtain a horizontal section.) In the smaller specimen there are sixteen primary septa; one of these is shorter than the rest, and occupies a non-prominent septal break.

The form is cornute and conical, with a tendency to become cylindrical in the adult stage. The larger specimen has a length of 12 millimetres and a calyx-diameter of 4 mm.

Mr. Leach informs me that the larger specimen is from West Angle and probably from the top of K_2, and that the smaller specimen is from Freshwater West and from Z.

These specimens appear to agree in essential characters with the description of *Cyathaxonia cornu* given by Edwards & Haime, and may be tentatively assigned to that species.

uniformly-expanding cone, whereas *C. rushiana* is, for the greater part of its length, purely cylindrical.

In many respects *C. contorta* approaches near to *C. costata*, M'Coy.[1] Compare Pl. XXIX, fig. 5. Both have the same form and dimensions; in both the septa are simple and thickened; both have sparse tabular intersections in the interseptal spaces; and both have a dense central area.

The differences are, however, well marked:—*C. contorta* has numerous septa (thirty to forty), and the septa are strongly bent. *C. costata* has a small number (twenty-five or less) of straight septa. In *C. costata* the epitheca is strongly costated; in *C. contorta* the costation is suppressed. *C. costata* is said to have a solid central axis; whereas, in *C. contorta*, the central area is made up of a dense ring surrounding a columellarian lath, the interspace being vesicular.

Evolution of *Cyathaxonia*.—It seems possible that the *Cyathaxoniæ* of the upper beds are derived by direct descent from the tubular variant of *Zaphrentis* cf. *Phillipsi*, by the strengthening of the septa and of the central tube.

The purely-radial type of septation, as exhibited in *Cyathaxonia rushiana*, probably indicates parallel development with *Densiphyllum* (see below) due to convergence. The central columellarian lath is also, most probably, an instance of convergence with the Lithostrotions and Clisiophyllids of the Upper Avonian.

The absence of *Cyathaxonia* from the South-Western Province may be accounted for, by the fact that *Zaphrentis* aff. *Phillipsi* does not there show any tendency towards the production of a central tube.

Densiphyllum. (Pl. XXIX, fig. 6.)

This genus is here employed in the sense in which it is interpreted by Thomson.[2] The corals included here have the cornute form which is common to both *Zaphrentis* and *Cyathaxonia*; they have the septation of *Cyathaxonia*, but differ from this genus in the absence of a well-defined central axis.

The most typical group of the genus is not represented in the Rush sequence, and the majority of the specimens collected from these beds may be more correctly termed Densiphylloid *Zaphrentes*. Densiphylloid *Zaphrentes* are occasionally met with throughout the sequence; but the earlier examples are mere variants of *Zaphrentis* cf. *Phillipsi*: whereas the upper forms are more specialized, and show relationship with *Cyathaxonia costata*, M'Coy. The figured specimen from the *Cyathaxonia*-Beds is of this type, and is a *Zaphrentis* in which the septation is purely radial and almost devoid of septal break; the wall is extremely thick, and the septa reach almost to the centre, where their thickened ends are webbed together by small tabular expansions. An example of a different type is noticed under *Amplexi-Zaphrentis*.

[1] 'Brit. Palæoz. Foss.' 1855, p. 109, & pl. iii C, fig. 2.
[2] Proc. Phil. Soc. Glasgow, vol. xiv (1882–83) p. 445.

LITHOSTROTION CYATHOPHYLLOIDES, sp. nov. (Pl. XXX, figs. 1, 1 *a*, & 1 *b*.)

Description.—Habit of growth: simple? (I have seen no definite evidence of compound forms.)

Form: cylindrical or elongate-conical.

Epitheca: thin, annulated by fine striæ and broad, low swellings.

Calyx: calyx-wall thick, and built up of numerous septa and of closely-packed interseptal vesicles; the inner slope of the wall is steep. Calyx-floor radiated by the primary septa, which extend to the centre. The central portion of the floor rises into a ridged tent, up the slopes of which run the primary septa; the ridge is crested by the thickened columellarian plate.

Horizontal section.—Peripheral area: often wanting, and never continuous round the whole circumference; where developed, it is thin and purely vesicular.

External area: broad, and closely radiated by the two cycles of septa; there are eight to ten rows of vesicles in the interseptal spaces.

Medial area: narrow, and almost clear of interseptal vesicles. The primary septa cross the area, but the secondary septa only project for a short distance into its outer margin.

Central area: completely radiated by the primary septa, which are crossed by about seven tabular intersections; the outer intersections are more closely approximated, so as to produce a conspicuous ring of denser structure. The columella is an elongated central plate.

Septa: not appreciably thickened in any part of their length. The primary septa are distinctly flexuous in the central area.

Measurements.—The central type has a diameter of about 21 millimetres, and has about forty-four primary septa; the relative proportions of the areas are best appreciated from the figure of a horizontal section (Pl. XXX, fig. 1 *a*).

Range and variation.—(1) The central type is abundant in the *Megastoma*-Beds; the specimens named *Lithostrotion* cf. *cyathophylloides* from the *Cyathaxonia*-Beds have only been examined in rough fracture.

(2) A mutation occurs somewhat sparingly in the Curkeen Limestone. This mutation is easily distinguished by its more numerous septa (about fifty) and by the less open character of the medial area, due to the greater elongation of the secondary septa (see Pl. XXX, fig. 1 *b*).

Comparisons.—(1) With other Lithostrotions: *L. affine* agrees in the considerable development of vesicles in the external area; but differs in the shortness of the septa, which do not extend to the centre. The large Nematophylla (that is, the basaltiform Lithostrotions) agree in:

(*a*) The extension of the septa to the centre; and (*b*) the conical tabulæ of the central area and the columella.

They differ, however, in the smaller number of their septa, as well as in their manner of growth.

(2) With the *Cyathophylla*: *Cyathophyllum* ϕ presents a very marked convergence on *Lithostrotion cyathophylloides*, for

(*a*) The characters of septa and vesicles are identical; and (*b*) both forms have well-developed tabulæ.

The only independent property in which *L. cyathophylloides* differs from *Cyathophyllum* ϕ is the elevation of the central portion of the tabulæ into tent-like projections, with the necessary accompaniment of a columellar plate.

(3) With the Clisiophyllids: The tent-like tabulæ of the central area, radiated by prolongations of the primary septa, most probably represent the ancestral character of the Clisiophyllids; but a true Clisiophyllid always exhibits a differentiation of the radii of the central area into distinct 'lamellæ.' Among the Clisiophyllids, *Lithostrotion cyathophylloides* most nearly resembles *Koninckophyllum*. Such a form as *Koninckophyllum* θ agrees with *L. cyathophylloides* in:

(*a*) The broad external area, completely radiated by the two cycles of nearly-uniform septa and closely packed with fine vesicles; (*b*) the elongation of the primary septa towards the centre; and (*c*) the columellarian plate.

Koninckophyllum θ differs, however, in its higher structural development, as shown by:

(*a*) The more numerous vesicles; and (*b*) the distinct, if rudimentary, development of lamellæ in the central area.

CLISIOPHYLLUM CURKEENENSE, sp. nov. (Pl. XXX, figs. 2 & 2 *a*.)

Description.—Simple corals, of elongate-conical form.

Horizontal section.—External area: narrow, radiated by both cycles of septa; the interseptal spaces occupied by a row of four vesicles (or fewer). Inner and outer walls strongly thickened.

Medial area: radiated by equal, thick, thorn-like primary septa, about 40 in number. The primary septa increase uniformly in thickness outward towards the inner wall. The secondary septa are also thorn-like, and project inward into the medial area for a very short distance from the inner wall. One primary septum is somewhat shorter than the rest, and forms a very inconspicuous septal break.

Central area: composed of numerous, concentric, tabular intersections, which are but slightly broken by the few and feebly-developed lamellæ. The outer margin of this area is very open in structure. The columellarian plate is strongly thickened and lentiform; it is confined to the middle of the area, but, owing to the strong development of one of the lamellæ, it is often apparently prolonged towards the septal break.

Range and variation.—*Clisiophyllum curkeenense* makes its first appearance in the *Megastoma*-Beds.

(1) This early form has a small central area, distinguished in a horizontal section by the strength and close approximation of the concentric intersections. The external area is very narrow, and for the most part merely radiated by septal teeth, which project into it from the thick outer wall.

(2) The central type occurs somewhat commonly in the Curkeen Limestone. In this form the external area is finely vesicular, and the septal prolongations which radiate the area are thin and inconspicuous. (Hence the differentiation of the external area is a conspicuous feature.) The central area is broader, and its structure looser, than in the earlier form.

Examples from the South-Western Province. — The earlier form occurs in the upper part of the *Syringothyris*-Zone; and I have a specimen from the Upper *Dibunophyllum*-Zone of Pendine that is almost identical with the Curkeen type.

EXPLANATION OF PLATES XXIX & XXX.

Plate XXIX.

Avonian Corals from Rush.

Fig. 1. *Syringopora* cf. *reticulata*, Goldf. (p. 313). Horizontal section and calices; natural size. R 10 k. *Megastoma*-Beds; coast-section, Rush.

2. *Zaphrentis* aff. *Enniskilleni*, Edwards & Haime (p. 315). Horizontal section; × 1·2. R 21 g. *Cyathaxonia*-Beds; coast-section, Rush.

Figs. 3, 3 *a*, & 3 *b*. *Cyathaxonia rushiana*, sp. nov. (p. 316).

Fig. 3. View of calyx and exterior (taken at 45° to the plane of symmetry); natural size. *Cyathaxonia*-Beds; Bradbourne (Derbyshire).[1]

3 *a*. Horizontal section of the same specimen; × 1¾.

3 *b*. Weathered fragment (showing the axial tube and enclosed columella); natural size. R 21 d. *Cyathaxonia*-Beds; coast-section, Rush.

Figs. 4 & 4 *a*. *Cyathaxonia contorta*, sp. nov. (p. 317).

Fig. 4. View of exterior (the calyx-wall is removed to show the columella); natural size. R 18 c. *Cyathaxonia*-Beds; coast-section, Rush.

4 *a*. Horizontal section of a larger specimen; × 1·2. R 21 d. *Cyathaxonia*-Beds; coast-section, Rush.

Fig. 5. '*Cyathaxonia*' aff. *costata*, M'Coy (p. 318). Horizontal section; × 1·5. *Cyathaxonia*-Beds; Bradbourne (Derbyshire).

6. *Densiphyllum* (Zaphrentoid subdivision) (p. 318). Horizontal section; × 1¾. R 21 d. *Cyathaxonia*-Beds; coast-section, Rush.

7. *Amplexi-Zaphrentis*, subgen. nov., variant convergent on *Zaphrentis* aff. *Enniskilleni* (p. 315). Horizontal section; × 1·2. R 21 d. *Cyathaxonia*-Beds; coast-section, Rush.

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[1] I had intended to illustrate this species solely from the Irish material; but, although specimens are abundant in the Rush section, the matrix does not lend itself readily to the cutting of good slices. The photograph of one such slice was quite unsatisfactory; and, though five more slices were cut, none of them was sufficiently good to serve as a representation of this very important zonal form. I consequently had to fall back upon the more tractable material from Bradbourne (Derbyshire). I can see no essential differences between the Bradbourne and the Rush forms.

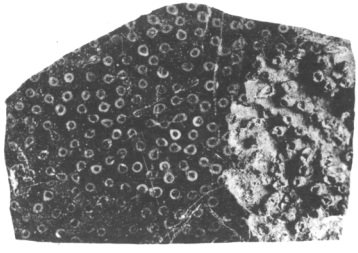

FIG. 1

FIG. 2

FIG. 3

FIG. 3b

FIG. 3a

FIG. 5

FIG. 4

FIG. 4a

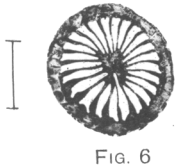

FIG. 6

FIG. 7

AVONIAN CORALS FROM RUSH (COUNTY DUBLIN).

J.W. Tutcher, Photo. *Bemrose, Collo,*

FIG. 1

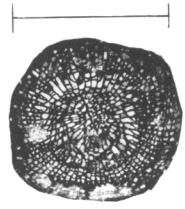

FIG. 1a

FIG. 1b

FIG. 2a

FIG. 2

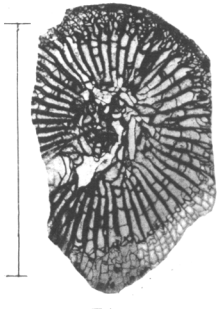

FIG. 5

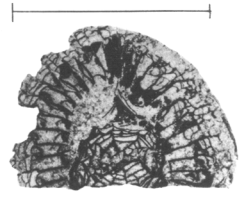

FIG. 3

FIG. 4

FIG. 7

FIG. 6

AVONIAN CORALS AND BRACHIOPODS FROM RUSH (COUNTY DUBLIN).

J. W. Tutcher, Photo. *Bemrose, Collo.*

PLATE XXX.

Avonian Corals and Brachiopods from Rush.

Figs. 1, 1 *a*, & 1 *b*. *Lithostrotion cyathophylloides*, sp. nov. (p. 319).
Fig. 1. Calicular view (showing the columella cresting a conical tabula); natural size. R 11 g. *Megastoma*-Beds; coast-section, Rush.
1 *a*. Horizontal section; slightly enlarged. R 11 a. *Megastoma*-Beds; coast-section, Rush.
1 *b*. A mutation. Horizontal section; × 1·2. Curkeen Limestone, Curkeen.
Figs. 2 & 2 *a*. *Clisiophyllum curkeenense*, sp. nov. (p. 320).
Fig. 2. Horizontal section; slightly enlarged. Curkeen Limestone; Curkeen.
2 *a*. A less-specialized variant. Horizontal section; slightly enlarged. R 11 a. *Megastoma*-Beds; coast-section, Rush.
Figs. 3, 4, & 5. Complex structural types cited in the faunal lists.
Fig. 3. Carcinophylloid *Clisiophyllum*. Horizontal section; slightly enlarged. R 10 j. *Megastoma*-Beds; coast-section, Rush.
4. Campophyllid. Horizontal section; slightly enlarged. R 17 b. *Cyathaxonia*-Beds; coast-section, Rush.
5. Cymatiophylloid Clisiophyllid. Horizontal section; slightly enlarged. R 21 h. *Cyathaxonia*-Beds; coast-section, Rush.
Fig. 6. *Productus* cf. *fimbriatus* (p. 308). Pedicle-valve; slightly enlarged. R 12 b. Top of *Megastoma*-Beds; coast-section, Rush.
7. *Syringothyris subconica* (Martin) (p. 311). Pedicle-valve; natural size. R 21 d. *Cyathaxonia*-Beds; coast-section, Rush.

DISCUSSION.

The PRESIDENT congratulated the Authors on this very interesting paper, and felt that it must be a source of gratification to Dr. Vaughan to see that his classification, founded upon study of the Bristol area, was being applied to an ever-widening tract. He was interested in many of the structures which had been projected on the lantern-screen: they certainly reminded him of structures seen among the knoll-like masses of limestone described by Mr. Tiddeman in the West Riding of Yorkshire.

Mr. G. W. LAMPLUGH, from personal experience of the section, heartily congratulated the Authors on their success in interpreting its intricacies. The classification of the Carboniferous Limestone in Ireland, based hitherto on lithological characters, stood in much need of revision under modern methods of research. The coast between Rush and Skerries offered the most favourable section known to the speaker for the first stages of this work; and he was delighted when Dr. Matley undertook the task, being assured that valuable results might be expected. The present paper justified this expectation, and promised well for the further results to be obtained from the remaining portion of the section, between Loughshinny and Skerries. He particularly hoped that this further work would demonstrate beyond doubt whether the Rush Conglomerates and the Skerries Conglomerates do actually represent two distinct and widely-separated horizons, as Jukes believed, since on this matter the interpretation of the structure of this Carboniferous basin largely hinged.

Mr. W. A. E. USSHER thought that the photographs exhibited

furnished an excellent object-lesson in rock-structure, and suggested such constant repetition, that he wished to ask whether the thickness assigned to the Rush Slates might not be exaggerated. The nodular limestone strongly suggested the folding of thin bands on their axes of contortion and in-sheared with the slates. He also commented on the apparent passage of limestone in beach-reefs into slates with chert and decomposed limestone-bands in the cliff, as suggestive of the sudden thickening of limestone-bands, and this tended to deprive lithological character of some of its value as an indicator of horizon in the Carboniferous System.

Dr. F. A. Bather enquired whether the term Avonian was intended to apply merely to the Carboniferous Limestone Series of the South-West of England, or whether it was intended to denote a division of Carboniferous time. If the latter, then how was the term to be justified when there already existed a 'Bernician Epoch,' including the Viséan and Tournaisian Ages?[1]

Dr. Vaughan thanked the President for his kind remarks. In reply to Dr. Bather, he pointed out that the term Avonian had already been defined in his earlier paper dealing with the Bristol sequence.[2] As a stratigraphical term, Avonian denotes the whole series of deposits, of which the zones from *Cleistopora* to *Dibunophyllum* are the constituent parts. As a necessary consequence of its faunal basis the term is also an index of relative time, and Avonian time at any place denotes the time during which all the zones from *Cleistopora* to *Dibunophyllum* were being deposited at that place. The introduction of such a term satisfies a long-felt want, seeing that 'Carboniferous Limestone' lacks all definiteness. In the South-Western Province 'Carboniferous Limestone' only denotes a portion (and that a variable portion) of the sequence. Outside the South-Western Province the use of the term is hopelessly misleading, since it suggests a correlation which is often entirely false (for example, the 'base of the Carboniferous Limestone' may be a deposit of *Dibunophyllum*-age).

Dr. Matley stated that he had invited the attention of geologists to the peculiar stratigraphy of the limestone-bands in the Rush Slates, as he thought that they might throw some light on the structure of 'limestone-knolls' referred to by the President. He hoped, before long, to complete the examination of the coast-section nearer Skerries, and then he might be able to ascertain definitely the horizon of the second conglomerate near that locality, which he thought at present belonged to a horizon higher than that of the Rush Conglomerate.

In reply to Mr. Ussher, the speaker stated that the thickness of the beds as shown in the vertical section was thought to be approximately correct; but, owing to the obscurity of the dip in places, some modification of the estimate given in the paper might be necessary.

[1] See Renevier's 'Chronographe Géologique,' 2nd ed. 1897.
[2] Quart. Journ. Geol. Soc. vol. lxi (1905) p. 264.