IV.—FURTHER NOTES ON CRINOIDEA.

BY JOHN ROFE, F.G.S.

(PLATE XI.)

DURING several years I have had frequent opportunities, in my spare time, of collecting and studying the Crinoidea, particularly those of the Carboniferous formation; but I have not had time, nor do I feel competent, to treat this subject fully in all its bearings. Perhaps, however, a few further notes on what I have observed in connexion with them, and in their relations with the recent as well as with those found in the several geological formations, may have an interest for some of your readers, or may be suggestive of further examination by some one better qualified, by physiological knowledge, for the inquiry.

Crinoidal Limestone, independent of the palæontological interest it possesses, has considerable geological importance, as from it may be deduced evidence of alternations in the depth of the sea in which the Crinoids flourished, sometimes, from their condition, suggesting great depth and clear water, and sometimes shallow water adjacent to a shore, or at an intermediate depth; and the great abundance of these remains, found under these different circumstances, make them worthy of more consideration in detail than they have yet received. Crinoids occur in most of the geological formations, particularly in the Palæozoic series; but they are found in the greatest profusion, both in number and in variety of species, in the Mountain Limestone: and I will therefore take this formation as the type, as most of the remarks I may make on it will apply to other strata in which Crinoids in any number occur.

In many places, particularly in the Pennine Chain in Westmoreland, Lancashire, Yorkshire, and Derbyshire, beds of this formation are composed almost entirely of portions of the columns or stems of Crinoids of different genera and species, varying from one to eighteen lines in diameter, but generally in short lengths.

In this mutilated condition these stems frequently occur in beds some feet in thickness, and so cemented together that they form a hard rock or marble, which takes a good polish, and is extensively used in this district for mantelpieces, tables, and other decorative purposes. One circumstance, however, is very remarkable, that amongst the innumerable portions of the columns, a calyx or head of any species is very rarely indeed found in the hard Limestone or marble rock itself, and what are found are generally in relief imbedded only partially in the upper surface of the rock and covered with shale or other parting between the Limestone beds. Those found with the arms, or with more than a few plates of the column, are, I believe, invariably in this condition. Sometimes the Crinoidal *axuvie* are more or less mixed with shells and corals, and are less consolidated, and can be used only as a building-stone or for lime-burning; and in other cases the fossils are dispersed in beds of calcareous or agillaceous shale between the beds of Limestone. The heads, however, are occasionally found in considerable numbers,

Mintern Bros. imp.

To illustrate Mr. Rofe's paper on the structure of the Crinoidea.

detached and dispersed, in these interjacent shale-beds, the arms and columns generally entirely removed from them, or with exceptionally a very few plates left attached. The nature of the parting beds varies very much. In some cases they appear to consist principally of broken or small fossils, with a mixture of more or less argillaceous matter; and these beds are generally thin and friable, and may be called rotten, and in them many fossils are found which may easily be freed from the matrix whilst fresh from the quarry. In other cases the parting beds are sandstone, and in others argillaceous shale, these being generally the thickest.

These various conditions of the Limestone alluded to may arise from differences of the circumstances, both as to the depth of the sea under which the fossils were deposited, and the vicinity of land. Let us consider first the hard rock or marble. This, from the structure, appears to have been deposited in deep clear water, because the calcareous base or cement which holds the fossils together is so transparent and free from foreign matter that their organization may frequently be distinctly seen when the marble is polished. But in this marble, as above stated, very little besides portions of columns is found, although, from the thickness of the beds, they must have been a long time accumulating, and are evidently the product of many succeeding generations. If this be so, the question at once arises—What has become of the heads? In endeavouring to answer this, I must refer to some notes on the Crinoidea published in Vol. VIII. of this *MAGAZINE*, p. 241, in which it was suggested that all the ossicles and plates of these animals were invested in and held together by a membrane, which, in case of the death of the animal, would decompose, and thus allow the plates to fall asunder. The smaller surfaces in contact in the joints of the comparatively thin plates of the head, and of the arms and pinnules, would be the first so to decay, and the plates and ossicles would be dispersed before the decomposition of the larger surfaces between the columnar plates would permit their separation. These, however, would eventually fall into a mass, and be cemented together in a manner similar to the Coral Reefs described by Mr. Jukes,¹ and thus form a bed for a succeeding generation, which one after another would follow the same course so long as the circumstances under which the growth and deposit may take place remain the same; and the great thickness of some of the Crinoidal beds is sufficient evidence of long-continued repetition, and the beds so deposited would probably be similar in every respect as to the hardness and quality of the stone. But if from any cause the sea became more shallow, the nature and hardness of the bed would be different; and if currents brought the surface soil denuded from a neighbouring land, and deposited it on these animals, they would be destroyed by it and buried before decomposition took place, and they would thus be held together and preserved nearly or perhaps entirely whole, and the denuded soil would form the parting bed on the limestone, and thus cover and protect the fossil. That this has been the case is evident in many

¹ Jukes and Geikie's *Manual of Geology*, 1872, pp. 388 and 389.

Limestone beds, particularly in the slabs of the Upper Silurian beds at Dudley; and the Apiocrinite bed of the Great Oolite covered by Bradford Clay, described by Lyell,¹ is a very apt illustration of this process.

On the other hand, to account for the absence of these heads, it has been suggested that the Crinoids may have been the larval state of *Palæocomatula*, as the recent *Pentacrinus Europæus* is of the *Comatula*, and that the columns were the residue left when the animal became free. But there is the serious objection to this theory that no such free *Comatula* has been found fossil in any formation in which the columns are abundant; and although this is only negative evidence, it acquires considerable weight when we find that the construction of the column is opposed to this supposition, for they were evidently of continuous, and probably of slow growth, increasing in diameter by exogenous accretion, which may readily be elicited from the columns themselves. At page 351 of the sixth volume of this MAGAZINE, this mode of the increase of the diameter of the column was suggested from the fact that corals attached to them whilst young and of small size became surrounded and invested by the new layers so added. The same mode of growth may be inferred from the side-arms, as the central canal of these branches off from that of the column whilst the columns are small; and as the diameter of this increases simultaneously with that of the side-arm, a cup is necessarily formed, increasing in depth as the column increases in diameter, so that the side-arm in a full-grown specimen appears to be inserted in a conical hollow or pit in the column (Fig. 1).

A periodic enlargement of the diameter of the column is sometimes indicated by the striæ on the faces of the joints, as in well-preserved specimens of some species these striæ bifurcate at certain distances as they recede from the centre (Fig. 3); and in weathered specimens, as well as in slices cut for the microscope, where metamorphic action has not effaced the structure, concentric rings of increase may frequently be traced, similar in appearance to those observable in the trunks of exogenous trees (Fig. 4).

When these animals grew under modified circumstances, as in a shallower sea, or in one disturbed by currents by which foreign matter might be mixed with them, but not in sufficient quantity to destroy them, the texture of the rock produced would necessarily be less uniform, and an inferior stone the result; so that, as a general rule, the deeper the water in which the Crinoids lived, or the further from land, the purer and harder would be the limestone deposit, whilst the reverse would be the case in shallow water or near land. By elevation of the coast and of the bed of the sea, a Crinoidal deposit or colony might be brought nearer to land, the denudation from which would form shale or sand-beds, as the case might be; if these again, by the oscillation of the sea-bed, should sink, further Crinoid deposits might take place: and a repetition of this process may have been going on for ages, as these deposits are found of great thickness, with occasional beds of shale or other partings, sometimes thin, and at

¹ Lyell's Student's Elements of Geology, 1871, p. 320.

others of considerable thickness. Further, to show that such oscillations have taken place, we have evidence that sometimes Crinoids, after partial decomposition, were present and exposed to wind on a sandy shore. Many persons, when walking on the shore of our own coasts, probably may have found the tests of sea-urchins blowing about, partially filled with the fine dry sand of the beach. If these are afterwards blown into a clay or muddy deposit, so common in estuaries, they would be filled up with the mud and buried. These, if found hereafter in a raised bed, partially or entirely fossilized, would present much the appearance of Fig. 5, representing the section of a *Rhodoerinus*, found in a shaly bed in the Mountain Limestone at Clithero; the lower part of the fossil being filled with fine sand (siliceous and calcareous), the upper part with mud very similar to the argillaceous calc-shale of the bed in which it was found: and similar cases are not very uncommon in bivalves and other fossils from these beds. In the Salt Hill Quarry at Clithero there is a thick bed of Crinoidal limestone, composed, as in the beds above named, almost entirely of portions of columns which have evidently been so exposed on a shore and subjected to a similar process. In almost every case the centre of the circular column to which the *fibro-cartilaginous* process is confined being decomposed and removed, the cavity has been partially, or sometimes entirely, filled up with sand, as in Fig. 6, the fine sand frequently containing, as in the case above alluded to, small portions of the channelled arms and of the minute pinnules or tentacles which fringe the arms of the Crinoid, thus demonstrating the disintegration of these parts of the animal before the columns entirely broke up. That part of the cavity which is not occupied by the sand is often full of transparent calc-spar.

Note on Variations in the Construction of the Columns.

In the paper above alluded to, in Vol. VIII. p. 241, of this MAGAZINE, it was stated that a fibro-cartilaginous process ran longitudinally along the interior of the column, the rays, and of the side-arms, by which flexibility and the power of regulating the movement were given to these parts, and in illustration sections of a recent *Pentacrinus* are given, in which the membranes were manifest. It was also stated that the longitudinal fibres were differently disposed in different genera, in some cases surrounding and adjacent to the central canal, and in others in bundles or lobes round the canal, but towards the exterior of the column. The first arrangement appears to apply to round or elliptical, and the second to radiated pentagonal or polygonal columns, irrespective of their geological age.

In the last volume, Vol. IX., at page 387, Mr. J. E. Lee gives a section of a sub-quadrangular column of a *Cupressocrinus* from the Devonian formation, very similar in condition to the Chert specimen from the Mountain Limestone (Fig. 8, Pl. VI., Vol. VIII.); but in the Devonian the cast of the central canal is surrounded by four and sometimes, Mr. Lee states, five smaller columns, as shown in Fig. 3 in his paper. These I take to be siliceous pseudomorphs of the central canal, and of bundles of fibres similar to those shown in

the recent *Pentacrinus* at Figs. 1 and 6, in the illustration to my paper as above, but which are not seen in the Chert specimen from the Mountain Limestone, as the fibres passed through the central screw-like portion, and not in bundles. In the Liassic *Pentacrinites* the fibro-cartilaginous lobes are disposed very similarly to those in the recent species, having a ring of pores round the central canal, and five lobes radiating from it, as in Fig. 7, whilst in the elliptical column of the Mountain Limestone *Platycrinus* (Fig. 8), and in the circular column of the Oolitic *Apiocrinus* (Fig. 9), the pores are distributed round the centre canal. I have also some portions of sub-pentagonal columns from Clithero, differing from those of other genera found in the Mountain Limestone in that district, which are generally circular in section. These vary in diameter from half an inch to more than an inch; a section of one is shown in Fig. 10. A thin section under the microscope shows the fibro-cartilaginous structure round the inner edge of the outer ring of the column, but in no instance have I found the central portion so perfect as to show the central canal or any organization. No head has been found which can be supposed to belong to these columns, a remark which applies to many other columns, and most particularly to the larger ones, frequently found abundantly in the Limestone. Probably this may be accounted for by the decomposition of the investing membrane above alluded to.

By the kindness of Mr. E. Hollier, I have procured pieces of columns from the Silurian formation at Dudley, including *Taxocrinus*, *Periechocrinus*, *Actinocrinus*, *Marsupiocrinus*, *Cyathocrinus*, and two columns undetermined, as they were without heads. Of these I have had slices mounted for the microscope, and find on examination that, although there appears to be a general similarity in construction with the round columns of the Mountain Limestone, as they are more metamorphosed by crystallization, the details are more difficult to distinguish. Some of them exhibit pentaphylloid sections of the central canal, as the *Taxocrinus* and *Cyathocrinus*, whilst the *Marsupiocrinus* shows a rosaceous section, the petals being wide and the divisions between them forming very acute angles; but I cannot satisfactorily make out the fibro-cartilaginous structure round the canal, though, from appearances, it is probable that it would be found by further examination with a great number of specimens.

Note on Euryocrinus (Phillips).

This Crinoid, which, from its rarity and the very imperfect state of the specimens hitherto found, is little known (neither the column, arms, nor dome having been recognized), is yet interesting from the peculiarity of the junction of some of the plates which form the cup. The only published notice of this genus which I have been able to find is in Phillips' *Geology of Yorkshire*, part ii. p. 205, and figured in plate 4, figs. 14 and 15, which appear to be drawn from two specimens in the Gilbertson collection now in the British Museum; the description given being merely, "Pelvic opening pentagonal; arrangement of plates like *Encrinus*, internal cavity very large." A

third, and in some respects a rather more perfect specimen, from Clithero, is now in my hands, and from it, with the help of those in the Museum, the genus may be, in some respects, more fully described. Using M. de Koninck's nomenclature of the plates, it may be represented as having a base pentagonal and tripartite, small and pierced for a pentaphylloid central canal; subradials, four pentagonal, about as wide as high, one hexagonal, one and a half times as high as wide, which is the first anal plate. The base-lines of two of the pentagonal and of the hexagonal plate are not quite straight, but fit into the very obtuse angle formed by the junction of the plates of the base. There are five sets of primary radial plates, the third plate bifurcating, or sometimes the fourth, even in the same specimen, an irregularity which I have observed occasionally in the *Actinocrinus*. All the radials are about twice as wide as high, and are thick, and overlap on the lower side, falling over and hiding a recess in the plate under it, making the second and third radials appear to be concentrically curved both top and bottom, but at the back of the plates the joints are straight, as shown on the face as in Figs. 11, 11a, and 11b is a section of two plates showing the overlap. The joints are wrinkled on the face and at the angles rather more coarsely than is the case with many other Crinoids. This overlap must add to the strength of the unusually wide cup, and, so far as my experience goes, it is peculiar to this genus. Of the inter-radial plates one series consists of a single row standing on the anal plate; the others are irregular, but generally similar in arrangement to those of the *Actinocrinus*.

EXPLANATION OF PLATE XI.

- FIG. 1.—Cross section and side view (Fig. 1a.) of a column and side arm, showing the branching of the central canal of the side-arm from that of the column, and on the side view showing the obtusely conical seat of a side-arm.
- FIG. 1b.—Conical end of a side-arm detached from its seat.
- FIG. 1c.—Cross section of a column, through two side-arms, showing the connexions with the central canal.
- FIG. 2.—Side view of a column and side-arms, showing the gradual expansion of the plates of the column to suit the growth of the side-arm.
- FIG. 3.—Portion of a section of a column, with bifurcation of the striae. The central portion decomposed.
- FIG. 4.—Portion of a large weathered column showing concentric rings of increase.
- FIG. 5.—Section of *Rhodocrinus*, the lower part of the interior filled with consolidated sand.
- FIG. 6.—Section of a column partially filled with consolidated sand, the remainder of the interior being subsequently filled with Calc-spar.
- FIG. 7.—Section of a column of a Liassic Pentacrinite.
- FIG. 8.—Section of an elliptical column of Mountain Limestone *Platycrinus*.
- FIG. 9.—Section of a column of *Apicrinus* (Oolitic), showing structure and rings of increase.
- FIG. 10.—Section of a subpentagonal column from Mountain Limestone.
- FIG. 11.—Side view of part of the calyx of *Euryocrinus*, showing arrangement of radial and inter-radial plates.
- FIG. 11a, 11b.—Face and section of two radial plates of *Euryocrinus*, showing the overlapping of the plates.