agreement with the above characteristics and those of the latter group. Its alumina is as high as that of the Australites. The alkalies are low, but equally correspond with the position of the alkalies of the Australites. There is also more agreement between the amount of iron and magnesia of the Australites and the Brunei tektite than between the latter and the Billitonites. Lime is irregular and comparatively low in position.

It is known that the quotient from the sum of iron and magnesia divided by the sum of the alkalies, as well as the ratios of lime, potash and soda are the evidences that distinguish the tektites from all terrestrial rocks. Besides this, moreover, they also characterize each group of the tektites, as is clearly shown in the following table (Table III). It is evident from the diagram and also from this table that the Brunei tektites do not correspond chemically with the group of the Billitonites, but that there is much resemblance between them and the Australites.

TABLE III.

Number of the Analyses.	$\frac{FeO + MgO}{Na_2O + K_2O}$	$CaO : Na_2O : K_2O$
Australites . . . I	2·5	6 : 2 : 2
IV	2·8	6 : 3 : 2
V	2·9	5 : 2 : 2
VI	2·7	5 : 2 : 3
VIII	2·6	6 : 2 : 2
Billitonites . . . 9	1·9	5 : 3 : 4
10	2·2	7 : 3 : 4
Brunei tektites . . a	2·9	4 : 2 : 2

Conclusions.—The tektites from Brunei in British Borneo are, geologically speaking, most likely of diluvial age. Their shape and sculpturing show nothing peculiar. Their physical properties correspond with those of Billitonites. In their chemical composition there is much resemblance between them and the Australites.

IV.—Studies in Edrioasteroidea, VII. Morphology and Bionomics of the Edrioasteridae.

By F. A. Bather, M.A., D.Sc., F.R.S.

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THERE have now been described all the known members of the Edrioasteridae and the very similar genus *Steganoblastus*, as well as a genus apparently connected with the Agelacrinidae but presenting some remarkable features, namely *Pyrgocystis*. It is proposed in this and the following Study to deal particularly with

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the Edrioasterid organization, first considering what the known facts of skeletal structure imply as to the general anatomy and mode of life, secondly comparing the structure with that of other echinoderms, especially the Asteroidea. Although it may be necessary to refer to various facts that fall to be dealt with in future Studies, still the present seems a convenient opportunity for this general discussion, because of the recent publication by Mr. W. K. Spencer of the introduction to "A Monograph of the British Palæozoic Asterozoa" (Feb., 1914, Palæontogr. Soc. vol. for 1913), by Dr. J. F. Gemmill of his highly important memoirs on the starfishes *Solaster endeca* (1911, Proc. R. Phys. Soc. Edinburgh, vol. 18, pp. 174–91; and Feb., 1912, Trans. Zool. Soc. London, vol. 20, pp. 1–71, pls. i–v) and *Asterias rubens* (Oct., 1914, Phil. Trans., ser. B., vol. 205, pp. 213–94, pls. xviii–xxiv, and March, 1915, Proc. Zool. Soc. London, pp. 1–19, pls. i–iii), and by Dr. A. F. Foerste of some suggestive "Notes on Agelacrinidæ" (Sept., 1914, Bull. Sci. Lab. Denison Univ., vol. 17, pp. 399–486, pls. i–vi).

First, then, as to the internal organization and mode of life of the Edrioasteridae. It is clear from the position of the three openings—mouth, anus, and water-pore—on one face, that that face was directed upwards as in normal Pelmatozoa. Apart from that argument, the general resemblance of *Edrioaster* and *Dinocystis* to the undoubtedly sessile Agelacrinidae clearly indicates a similar position with regard to the sea-floor, even though the edrioasterids in question may not have been permanently attached. *Steganoblastus* obviously was fixed by a stem of ordinary pelmatozoan character, and by the mechanical stresses thus set up its theca has been modified so as to present a remarkable resemblance to that of a blastoid. How this stem originated is suggested by the parallel history of *Pyrgocystis*, in which we seem to trace the gradual elevation of the loosely and irregularly plated thecal wall, as seen in *Cystaster*, through the low turret of *P. sardesoni*, to the elongate stem-like turret of *P. grayae* and the more regularly plated turret of *P. ansticei* and *P. sulcata*.

Another criterion of Pelmatozoa is: "Food brought to the mouth by a subvective system of ciliated grooves, radiating from the mouth." The evidence for this in all Edrioasteroidea is the presence of radiating grooves protected by cover-plates, which plates are particularly well developed in Edrioasteridae and *Steganoblastus*, and apparently immovable over the mouth-region.

The only pelmatozoan character not yet mentioned is the presence of "an aborally placed motor nerve-centre". The presence of such a centre in *Steganoblastus* at any rate may be inferred from the stem with its lumen (Study V, 1914, p. 202) and from the axial folds similar to those which in many crinoids are known to have afforded passage for the nerves from that centre (Study V, p. 197). The possible relation of the lobes seen on the adapical face of *Edrioaster* to a chambered organ, such as that with which this nerve-centre is connected in the crinoids, was discussed in Study II (1900, p. 202). It is, however, scarcely necessary to point out that a sessile or almost sessile form such as *Edrioaster*, without stem and without movable arms, had little or no need for such a motor nerve-centre. If we

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suppose the Edrioasteridae to be descended from forms with a more definite organ of attachment and with a moderately developed aboral nerve-system, we shall none the less expect to find that system considerably atrophied and leaving but slight traces. If, on the other hand, we suppose that the Edrioasteridae received their aboral nerve-system directly from the supposed anterior nerve-ganglion of some pre-echinodermal ancestor, *Dipleurula* or other, then again this will scarcely have been modified far in the direction of a motor centre. The same remark applies to any imaginable derivation of the Edrioasteridae from some echinoderm other than a Pelmatozoön, say a primitive Asterozoön.

The proof that the Edrioasteridae are Pelmatozoa in the full signification of that name has been laboured because the striking characteristic of this Family, more than of any other Edrioasteroidea, is just that strange resemblance to Asteroidea which suggested the second component of the Class name, and which will be fully discussed in the next Study.

Let us now consider more closely the Form and its relation to Fixation.

Edrioaster, *Lebetodiscus*, and *Dinocystis* have their rays curved like those of *Agelacrinus*, *Lepidodiscus*, and similar Agelacrinidae. This ensures a more or less circular outline of the theca or at all events checks any tendency to a star shape. That this curvature is secondary is an obvious conclusion from a comparison with the Agelacrinidae, from the facts of individual growth (Study IV, 1914, pp. 120, 121), and from the existence of the straight-rayed *Steganoblastus*. Further, the oldest known Edrioasteroid, *Stromatocystis* from the Middle Cambrian, has straight rays. This last form is pentagonal, with a tendency to be stellate; but it cannot therefore be inferred that its as yet unknown ancestor was more stellate. The assumption of a pentagonal or star shape is a consequence of the straight outgrowth of the food-grooves. All that we know of the evolution of those structures in the earlier Pelmatozoa indicates that, in race-history as in individual growth, they stretched gradually outwards from the mouth, and by degrees impressed a radiate symmetry on every part of the theca as well as on the internal organs. *Stromatocystis*, as will appear in a subsequent Study, affords no evidence of descent from an ancestor in which the radiate symmetry was more strongly marked than in itself. On the contrary, for this Cambrian genus, as for all the Ordovician Edrioasteroids, the natural inference is that they are descended from a simple sack-like, irregularly plated pelmatozoön with no more than the beginnings of radiation seen in its food-grooves, which at first were but three in number. (See Treatise on Zoology, 1900, p. 11; Study I, 1898, p. 545; Study V, 1914, p. 201; and A. Foerste, 1914, op. cit., p. 412.)

It is generally admitted that radiate symmetry of this kind can only have arisen in a fixed form, and that in the case of Pelmatozoa the fixation must have been by the apical end. Such fixation was retained, or perhaps emphasized, in *Cyathocystis* and *Steganoblastus*. *Stromatocystis*, however, the only Edrioasteroid as yet known from

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Cambrian rocks, was certainly not fixed, and can have had at most a loose and variable attachment. Between these extremes lie all the forms of attachment found in the Edrioasteroidea, differing from genus to genus, and even from species to species, according to the needs of the environment. Thus, evidence has been adduced to show that, in spite of Jaekel's contrary opinion, *Edrioaster* and *Dinocystis* were not actually fixed (Study II, 1900, p. 200; Study IV, 1914, p. 169). Direct evidence is wanting in the case of *Dinocystis*, but the indirect proof is the same as for *Edrioaster*, namely, that the fossils are never found resting on any hard surface, but have the apical face covered with shale or sand, which cannot have afforded a firm basis of attachment. It is by parity of reasoning that *Pyrgocystis grayae* and its Wenlockian successors are supposed to have been not fixed but inserted in a sea-floor of similar loose consistency, although *P. sardesoni*, in its firmer surroundings, seems to have been fixed.

The general situation of such Agelacrinidae as '*Agelacrinus*' sensu lato, *Hemicystis*, and *Streptaster*, upon the smooth hard surfaces of shells and similar objects, suggests a permanent fixation, and I can recall no very clear evidence to the contrary. Dr. Foerste, however, says (1914, op. cit., p. 407): "In all of the Ordovician species referred to *Agelacrinus* or *Lepidodiscus*, the animal evidently was capable of attaching itself to various objects for support, although this attachment was not permanent, and occasional specimens are found unattached." The nature of this temporary attachment is imagined by Dr. Foerste to have been essentially the same as that suggested by me for *Edrioaster* and *Dinocystis*. As explained in Study II (1900, p. 202), it is supposed that this was effected by an action comparable to that of a limpet or a sea-anemone or of any mechanical sucker. In all the species of Edrioasteridae the necessary elements of the theca were present, namely an apical concavity, a rigid frame, and a central area of flexible integument. We know, it is true, nothing of the muscles within the thecal cavity that may have raised up this central integument, but the radial muscles of the flexible-tested sea-urchin *Asthenosoma* indicate how readily the necessary muscles may have been developed. Another mechanism, however, may be conceived. If, as here maintained, the pores between the floor-plates of the subvective grooves led from podia fringing the grooves to ampullae within the thecal cavity, then the distension of the ampullae by influx of water through the hydropore, or by retraction of the podia, would exert hydraulic pressure on the walls of the theca and their flexible portions would be inflated. If now, the ampullae were contracted and all their contained fluid forced into the podia or even out through the hydropore, then the flexible parts of the thecal wall would necessarily be drawn inwards. Thus, if the thecal margin were resting on a sandy bottom, a vacuum would be created, with consequent sucker action.

In so far as this latter hypothesis helps to account for the presence of pores in the free Edrioasteridae, just so far does it fail to harmonize with their presence in the fixed *Steganoblastus* with its more rigid theca. Moreover, if the Agelacrinidae were attached by sucker

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action, their lack of pores prevents the extension of the hypothesis to them. It is, however, not only pores that are lacking, but also a plated apical integument, as may readily be proved by dissection or grinding either from above or from below, and by thin transverse sections (see further, W. K. Spencer, 1904, Proc. Roy. Soc., vol. 74, p. 43, l. 9, where for 'ventral' read 'dorsal'; also Foerste, 1914, op. cit., p. 409, § 13). Not that the absence of calcification would be the smallest bar to sucker-action, or to locomotion,[1] but it suggests that the animal rarely if ever relinquished its attachment.

The lobes of the flexible integument round the apical pole have been discussed more than once (Study II, 1900, p. 201; Study IV, 1914, p. 169). They have been found in all specimens of *Edrioaster* available for the prolonged preparation usually required; but this area is obscured in *Lebetodiscus*, and in *Dinocystis* all that can be traced is an occasional suggestion of an evagination (see text-fig. on p. 135, vol. 6, 1899) and foldings indicative of a stretched membrane (Study I, 1898, p. 546).

The number of lobes is five in the holotype of *Edrioaster buchianus*. In the specimens of *E. bigsbyi* the lobation is not so regular, but there are indications of the same pentamerism. Within the rounded margins of the lobes the integument is depressed, that is to say, withdrawn towards the interior of the theca. The lobes in *E. buchianus* were described as interradial, but in a form where the subvective grooves coil round from one radius into another, it is very difficult to decide upon the correct orientation of the apical face.

Whatever these lobes may mean, it is interesting to observe precisely similar structures, apparently with similar interradial position, figured by Jaekel in his *Thecocystis sacculus* (1899, pl. i, fig. 1 *b*) and described as an "Ansatzfläche" or "Anwachsungsfläche". In *Stromatocystis* also there is a pentagonal swelling with central depression round the apical pole, but the angles of the pentagon are prolonged in a distinctly radial direction.

This evagination may have had something to do with temporary fixation, but it does not reach as low down as the thecal periphery, and this function does not explain its quinquelobate structure. The only conclusions that can safely be drawn from the facts are that the shape indicates some rather firm internal organ or organs with quinque-radiate plan but without calcified skeleton. Beyond this all is pure speculation.

(*To be concluded in our next Number.*)

V.—The Zonal Lake Basins of sub-Alpine Switzerland.

By C. S. Du Riche Preller, M.A., Ph.D., M.I.E.E., F.G.S., F.R.S.E.

IN two papers read before the Geological Society in 1904[2] I showed that the five principal lake basins of sub-Alpine Switzerland lie in a zone which is parallel to the Alps, and that this zone lies almost

[1] Cf. G. H. Parker, "The Locomotion of Actinians": Science, March 26, 1915, p. 471.

[2] Q.J.G.S., vol. lx, pp. 65, 316, 1904.

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