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THE RESULTS OF DEEP-SEA INVESTIGATION IN THE
TASMAN SEA.

I.—THE EXPEDITION OF H.M.C.S. "MINER."

2. THE COLONIAL RADIOLARIA OF THE TASMAN SEA.

By PROF. W. A. HASWELL, M.A., D.Sc., F.R.S.

(Plate liii.).

The colonial Radiolaria collected during the two-days cruise of H.M.C.S. "Miner" in June, 1906, were mostly obtained at a distance of over fifty miles off the coast. Here, probably on account of the strong southward-flowing current, with a surface temperature of 65° C, surface life was very abundant and varied. Owing to the unfavourable weather it was impossible to do more than drag the tow-net for a time within a few feet of the surface, and the specimens obtained had to be somewhat summarily disposed of. The fixing solution employed—a copper sulphate and corrosive sublimate combination—though very efficient as regards most of the surface organisms, was not entirely successful in the case of the colonial Radiolaria, having had, apparently, a softening effect on the jelly which led to the disintegration of most of the colonies. Fragmentary though the specimens are, the individual zooids prove to be remarkably well preserved. To complete the observations here recorded, however, the study of further material preserved in other ways, and of living specimens will be necessary, and what follows can only be regarded as a preliminary account of the colonial Radiolaria of this region.

The points of more general interest, to which attention is directed, are: (1) The observation in a species of *Collozoum*, as well as in *Belonozoum atlanticum* and *Rhaphidozoum pandora* of bodies which appear to be zooids that have undergone conversion into masses of microspores; (2) The observation in *Collozoum arcuatum*, n. sp., of a special phase in the life-history of the *Xanthellæ*.

It is somewhat remarkable that so few Radiolaria have been recorded from the Tasman Sea. Of the colonial forms I find record of only three species having been found in that region, viz., *Sphaerouzoum octoceras*, Haeckel, *S. australe*, Haeckel, and *Collosphaera fragilis*, Haeckel. The reason for this is, doubtless, that so little plankton-net collecting has been done in the open sea. The Radiolaria, and more particularly the colonial forms, do

not seem to abound near the coast, and, as far as Port Jackson and Broken Bay are concerned (and I have little doubt the same holds good of the other inlets), a simple Radiolarian of any kind is a *rara avis* in the surface net, and the colonial forms, so far as my experience goes, never occur.

None of the three species mentioned above occur in the present collection. On the other hand it comprises about seven species previously known from other parts of the ocean.

Genus COLLOZOOM.

The absence of skeletal parts in the genus *Collozoum*¹ renders the identification of the species in that genus a matter of considerable difficulty—particularly when one has to deal with preserved material, in which the form of the colony may not be recognisable. This difficulty is increased by certain discrepancies between the determinations of Haeckel on the one hand and of Brandt on the other. Thus with regard to the characters of the original species, *C. inerme*, supposed by the former to be cosmopolitan, and to be subject to considerable variation, there is a wide divergence in the statements of the two authors. According to Haeckel's description in the "Monographie,"² in this species the zooids are usually spherical, but may be compressed spheroids, or lens-shaped, or, rarely, elliptical, and there is a thick, often double, capsular membrane; in the "Report"³ the specific name is restricted to forms with spherical zooids and a thin, simple-edged membrane. According to Brandt⁴, on the other hand, in the species in question the zooids are discoid or irregular, and a membrane is entirely absent.

Of the specimens of *Collozoum* obtained during the "Miner" excursion a considerable proportion belong to what may be termed the *C. inerme* group of Haeckel's sub-genus *Collodivium*—forms in which the prevailing shape of the zooid is spherical, and in which there is a single, relatively large, oil-globule. All the leading modifications and phases are represented—except that there are none in which a capsular membrane can positively be said to be absent.

Until further material has been obtained I think it better to defer any attempt to deal systematically with this group. But

¹ With the exceptions to be referred to later.

² Haeckel, E.—Die Radiolarien. Eine Monographie, 1862., p. 522.

³ Haeckel, E.—The Radiolaria. Chall. Rep., Zool., xviii., 1887, p. 25.

⁴ Brandt, K.—Die Koloniebildende Radiolarien: Sphaerozoen, (Fauna u. Flora Golfes v. Neapel, xiii., 1888., p. 6.)

there are three members of it which present certain features of special interest. These I will distinguish as *C. armatum*, n. sp., *C. alpha* and *C. beta* respectively.

COLLOZOOM ARMATUM, *sp. nov.*

(Plate liii., fig. 1).

The entire absence of skeletal parts is given by Haeckel (Rep. p. 24) as one of the diagnostic characters of the genus *Collozoum*. Brandt⁵, however, states that in *C. hertwigi* there may be present completely isolated needle-like spicules. Spicules identical with those of various *Sphaerozoum*-species are present in several of my specimens of *Collozoum*, but, from their mode of occurrence, these are undoubtedly to be looked upon as of the nature of foreign bodies. In the form now to be described, however, there is a true skeleton of an elementary character; although in other respects there is no departure from the character of the genus *Collozoum*.

The form of the colony is unknown, the species being represented only by two fragments, which, however, show quite distinct phases. The zooids in both are spherical, 0.1 mm. in diameter, with a distinct capsular membrane. One of them is in a fairly early stage of anisoporous reproduction, each capsule enclosing a large number of nuclei arranged in the characteristic way in rounded groups. The other is in the isoporous phase. In the latter the oil-globule is present; in the former it is not distinguishable. In neither are pseudopodia or pseudopodial matrix recognisable. The skeletal elements are extremely slender, simple fibre-like spicules in the inter-capsular jelly; they are about 0.2 mm. in length or a little longer, with a diameter of not more than 0.001 mm. The small size of the fragments precluded any attempts to determine the composition of the spicules.

COLLOZOOM (ALPHA).

(Plate liii., fig. 2).

There is only one specimen of this form, a complete colony of spherical shape, only about 2 mm. in diameter. The zooids are apparently in the vegetative phase. They are spherical in form; only in one case is there a constriction indicating an early stage in vegetative multiplication. In each capsule there are 20-30

⁵ Brandt, K.—Die Kolonebildende Radiolarien: Sphaerozoen, (Fauna u. Flora Golfes v. Neapel, xiii., 1888, p. 228).

nuclei, separated from one another by intervals filled with granular protoplasm; these are not arranged in a single layer. The nuclei appear as completely homogeneous masses of chromatin of somewhat irregular shape; in several cases phases of direct division are observable. Around the whole of the nuclei of each capsule is a thick layer of granular protoplasm. The outer boundary of each zooid is quite sharply defined, but, if a capsular membrane is present, it is not distinguishable, and must be extremely delicate. Pseudopodial matrix and pseudopodia are not to be made out. There is a single spherical oil-globule in each zooid. About 12-15 *Xanthellæ* are closely applied to each zooid, and there are also many in the intermediate spaces. The zooids are about .07 mm. in diameter; the nuclei about .01.

So far there is nothing to distinguish this form from an early vegetative phase of one of the *C. inerme* group. But, scattered over the surface of the colony, are some fifty bodies which differ entirely from the ordinary zooids. These are rounded masses of granular matter most of which are of about the size of the zooids, while a few are slightly larger, and some are considerably smaller. These are all superficial in position, superficial to all the zooids and to all the *Xanthellæ*, most of them projecting on the surface, and some being covered externally only by a very thin layer of the gelatinous matrix.

In this, as well as in the other colonial forms to be subsequently referred to in which they occur, these bodies are rendered conspicuous in my preparations owing to their not being affected by the staining agent used (paracarmine), and, in the cleared specimens, appearing very bright and yellowish in colour. When one of them was removed, and, after being returned to alcohol, acted on with hæmatoxylin, a distinct staining effect was produced, certain granules in the mass becoming more strongly effected than the rest. Owing, probably, to the condition of the material, the component parts of these granular masses could not be definitely isolated. But I have little doubt from their mode of occurrence that we have here to do with masses of microspores of small size. In Brandt's classical monograph microspores and megaspores are stated to be developed in the same zooid in *Collozoum* and in *Sphaerouzoum*, and the allied genera, but, if the above view should be fully confirmed, this, if it is a rule, is subject to some exceptions. This, however, is a question which can only be definitely settled with the aid of living material.

COLLOZOU (BETA).

(Plate liii., fig. 5).

Another form of this *C. inerme* group is worth referring to

owing to a peculiarity of which at present I have no explanation. In this form, of which there are several specimens, all, unfortunately, fragmentary, the zooids have the usual spherical form, with a diameter of about .08 mm. They are in the anisoporous phase with numerous small nuclei (.008 mm. in diameter) arranged in rounded groups in the typical manner; and there is a large central oil-globule. There is a thin pseudopodial matrix giving off delicate pseudopodia which form a network. A few Algae adhere to each zooid and many lie in the interspaces.

There is a thin capsular-membrane; but this is almost hidden by a layer of minute bright bodies of about .0016 mm. in diameter, which adhere to its outer surface. Whatever may prove to be the nature of these bodies, there can be little doubt from the constancy of their presence in this form and in this alone, that they represent a definite structure or structures, and are not of the nature of an artifact.

COLLOZOOM OVALE, *sp. nov.*

(Plate liii., fig. 3).

The prevailing form of the zooids is elliptical; a few are constricted as if about to divide. Both of the specimens are in the vegetative phase, with few (4-10) nuclei in each capsule. The membrane is delicate, the protoplasm very granular. In place of an oil-globule there is an irregular space towards the centre giving off branching lobes from which finer channels pass out in a radiating manner through the protoplasm to the periphery. There are no pseudopodia or pseudopodial matrix. A very variable, though never very large, number of Algae are closely applied to each membrane; others occur abundantly in the interspaces.

The length of the longest capsule is 0.125 mm.; its breadth 0.05. The average length is 0.1, and the average breadth 0.05. The diameter of the nuclei is a little less than 0.01.

The nearest allies of this form seem to be *C. ovatum*, Haeckel,⁶ and *C. ellipsoides*, Haeckel.⁷ The former has a single central oil-globule, and the diameter of its zooids is two to three times as great as in *C. ovale*. The latter has a number of oil-globules, and the length of the zooids is even greater than in *C. ovatum*.

⁶ Haeckel, E.—The Radiolaria, Chall. Rep., Zool., xviii., 1887, p. 25.

⁷ Haeckel, E.—*Loc. cit.*, p. 20.

What may be a different phase of the same species differs from the above in having the capsular membrane much less distinct in the presence of numerous pigment granules in the intracapsular plasm. There is a similar lobed space representing the oil-globule, but it does not give off the narrow radiating channels, and it may be simple and rounded. The Algæ are not in any way specially related to the zooids.

COLLOZOOM ARCUATUM, *sp. nov.*

(Plate liii., figs. 4a-4c).

In this species, in which the form of the entire colony is unknown, the zooids are elongate and sausage-shaped. Each contains about twenty nuclei which are axially situated in a mass of vacuolated protoplasm with pigment. Within the capsule are a number of pigmented bodies of irregular shape and varying size. There are one or two oil-globules.

There are no *Xanthellæ* of the ordinary character, their place being taken by a number of problematical bodies (figs. 4a, 4b, and 4c), many of which are in close apposition with the capsules of the zooids, while others lie in the intermediate spaces. The foundation of each of these is a spherical cell with a central nucleus, a few large rounded granules in the cytoplasm and vacuoles. Arranged around the surface of the cell, which appears to have a distinct cell-wall, are a varying number (usually six to twenty) of bright-looking bodies of somewhat variable shape, usually concavo-convex, often with one or two grooves or notches.

The resemblance which undoubtedly exists between the bodies above described and the "extra-capsular bodies" described in detail by Brandt is a purely superficial one. The latter are derived from the zooids, and appear to represent a phase in a special process of anisoporous division. The bodies now under consideration, on the other hand, represent a phase in the life-history not of the Radiolarian, but of the *Xanthellæ*. These bodies in fact correspond (as far as can be determined in the fixed specimen) in every respect with ordinary *Xanthellæ* with the addition of the small bright objects symmetrically arranged around each.

In a few cases (Pl. liii., fig. 4b) the bright bodies are represented by an almost unbroken layer of the bright substance.

BELONZOUM ATLANTICUM, *Haeckel*.

Belonozoum atlanticum, Haeckel, The Radiolaria, Chall. Rep., Zool. xviii., 1887, p. 40.

To this species I refer several specimens which resemble one another and agree with Haeckel's description and figure in the character of the spicules. The entire colonies are more or less elongated and cylindrical. At least two distinct forms or phases are represented. In one the zooids are comparatively large (from 0.1 to 0.2 mm.), and each contains from one to three nuclei: there are many *Xanthellæ* in the layer (pseudopodial matrix) immediately surrounding the capsule. In the other form the largest of the zooids is about 0.1 mm. There are about half-a-dozen small nuclei in each, and there are very few Algae.

All the specimens contained the sharply-defined granular masses described as occurring in *Collozoum alpha*. These vary a good deal in size, but are, for the most part, considerably smaller than the zooids. In a complete colony there are about a dozen of them, all placed superficially.

The "Challenger" locality for *B. atlanticum* is the tropical Atlantic.

BELONZOUM HILLI, *sp. nov.*

This species forms spherical colonies. The spicules are all simple and unbranched, but are of two kinds. Those of one kind are extremely slender, elongated and curved, usually as long as, or somewhat longer than, the diameter of the capsules (0.15 mm.), and quite devoid of spines. The other set, which are much fewer, are shorter, usually straight, and beset with spines throughout their length—the spines being longest towards the ends. Between these two kinds are a number of intermediate forms—long, slender, usually curved, and spinose only, or chiefly, at the ends.

The capsules are large, about 0.15—0.24 mm. The outer portion of the intra-capsular protoplasm is granular and pigmented. In the interior are several—3-6—oil-globules of considerable size, and a number of nuclei, most of which are grouped towards the centre. Embedded in the pseudopodial matrix, which has a reticulate structure, are a number of Algae.

Brandt states that young specimens of *Sphaerouzoum* may have needle-like spicules only. But, as he states that all the young stages of the species of that genus which he had closely studied were more or less elongated—cylindrical or sausage-shaped, I think it is most probable that the species above described is to be looked upon as a *Belonozoum*.

RHAPHIDOZOOM PANDORA, *Haeckel*.

Rhaphidozoum pandora, Haeckel, The Radiolaria, Chall. Rep., Zool., xviii., 1889, p. 49, pl. iv., fig. 6.

Several specimens were obtained of a *Rhaphidozoum* which agrees closely with Haeckel's definition and figures of *R. pandora*, the only difference being that the acicular spicules are somewhat stouter. The intra-capsular plasm is coarsely granular, and usually contains a small number (1-6) of large nuclei, though in a few cases there are a larger number. In zooids with a single nucleus there is a rounded oil-globule: in those with several nuclei this has become irregular, sometimes branched. The few *Xanthellae* that are present are all closely applied to the capsular membrane. Masses of granules (microspores?) of the same character as those observed in *Collozoum alpha*, all smaller than the zooids, occur superficially here and there, some actually projecting on the surface.

One specimen differs from the others in having the spicules more strongly spinose, the connecting shafts of the geminate spicules sometimes being beset with spines, and the spines of a few of the spicules having short branches.

The "Challenger" locality is South Atlantic near Ascension Island.

RHAPHIDOZOOM BRANDTII, *sp. nov.*

The spicules consist of (1) exceedingly fine, smooth, needle-like spicules (2) 4-5 rayed spicules. The former are mostly aggregated in such a way as to form a layer investing each capsule. Of the latter there are two distinct varieties, smaller, which are smooth, and larger, which are spinose towards the ends of the branches. The capsules are large (about 0.15 mm). The needle-like spicules are from .15 to .3 mm. The largest of the rayed spicules are of comparatively gigantic dimensions, each ray being nearly 0.2 mm. in length.

From *R. acuferum*, Haeckel, this species differs in having the needle-like spicules smooth and straight. From *R. arachnoides*, to which it is also allied, it differs in having the radiate spicules spinose and the needle-like spicules straight, not curved.

SPHÆROZOOM QUADRIGEMINUM, *Haeckel*.

Sphaerouzoum quadrigeminum, Haeckel, The Radiolaria, Chall. Rep., Zool., xviii., 1887, p. 44.

The specimen referred to this species agrees in all particulars with Haeckel's description except in the dimensions of the largest spicules, which is given as 0.15 mm., nearly twice as large as any in my specimen. The zooids have a diameter averaging 0.07 mm. The intra-capsular plasm is coarsely granular: it contains four to eight nuclei. Five or six *Xanthellae* are closely applied to each capsular membrane, and there are none in the intermediate spaces.

The "Challenger" locality for *S. quadrigeminum* is the North Atlantic and the Azores.

A single fragment was obtained of a *Sphærozoum* which closely resembles the above in the form and dimensions of the spicules; but which has the zooids thrice as large.

SPHÆROZOU M ALVEOLATUM, *Haeckel*.

Sphærozoum alveolatum, Haeckel, The Radiolaria, Chall. Rep., Zool., xviii., 1887, p. 43, pl. iv., figs. 2, 3.

It is with some doubt that I refer to this species several specimens of a *Sphærozoum*. The alveoli, to the presence of which the species owes its name, are certainly absent; but there is a close correspondence in the form of the spicules, though their size is less in my specimens than the measurements given by Haeckel. The zooids in two of the specimens have a diameter of about 0.06 mm.; they contain granular plasm with a central oil-globule and about half-a-dozen nuclei. In certain respects these two specimens, though in the same phase, differ from one another. In the one the spicules are very numerous, and are definitely arranged around the zooids; in the other they are comparatively few, and are irregularly distributed. The former specimen has no *Xanthellae* in the interspaces between the zooids; while in the latter they are numerous.

A third specimen, which has very numerous densely aggregated spicules, has the zooids twice as large (0.1 to 0.12 mm.) and filled with a multitude of small nuclei.

S. alveolatum was obtained by the "Challenger" off Juan Fernandez.

SPHÆROZOU M GEMINATUM, *Haeckel*.

Sphærozoum geminatum, Haeckel, The Radiolaria, Chall. Rep., Zool., xviii., 1887, p. 45, pl. iv., fig. 4.

One specimen. Originally obtained by Haeckel in the Indian Ocean.

COLLOSPHÆRA HEDLEYI, *sp. nov.*

(Plate liii., fig. 6).

The tests are nearly completely spherical, with a number of short tubes irregularly scattered among small apertures which are less than half the diameter of the intermediate spaces. The tubes are never dilated externally, but always gradually decrease in diameter distally. There are about ten of them in each hemisphere, and about fifteen or sixteen of the small apertures in each half meridian. The intra-capsular protoplasm occupies only a small part of the space enclosed by the shell (about half the diameter). There are numerous Algæ within the shell. The diameter of the shell is .09 mm. The length of the tubes is .012; and their width at the base about the same. The small apertures are .005 mm. or less.

This species is distinguished from *S. socialis*, Haeckel, by the greater number of the tubes and the smallness of the other apertures. *S. fragilis*, Haeckel, which was obtained at the "Challenger" Station 165, differs widely in having tubes all over the surface.

COLLOSPHÆRA GLOBULARIS, *Haeckel.*

Collospæra globularis, Haeckel, The Radiolaria, Chall. Rep., Zool., xviii., 1887, p. 94.

One specimen of this widely-distributed species.

COLLOSPHÆRA HUXLEYI, *J. Müller.*

Collospæra huxleyi (J. Müller), Haeckel, Die Radiolarien, Eine Monographie, 1862, p. 534, pl. xxxiv., figs. 1-11; The Radiolaria, Chall. Rep., Zool., xviii., 1887, p. 96.

Several specimens.

COLLOSPHÆRA UNIFORMIS, *sp. nov.*

(Plate liii., fig. 7).

The tests in this species are nearly regular, thin-walled spheres, perforated by rounded apertures, about ten in the half meridian, the intervals, for the most part broader than the apertures. There is usually only one larger well-defined circular aperture with a raised margin; sometimes there are two of these larger apertures. They obviously correspond to the tubes of *Siphonospæra*, but are much less prominent. The tests are 0.06 mm. in diameter; the small apertures about 0.05 mm., intervals about 0.01 mm.; the larger apertures 0.01.

In the presence of the single larger aperture this species resembles *C. pyriformis*, Haeckel, but differs widely from it in the shape and size of the test and the dimensions of the apertures.

EXPLANATION OF PLATE LIII.

Lettering—*g*, granules; *n*, nuclei; *o*, oil-globules; *s*, spicules;
x, Xanthellæ.

- Fig. 1. *Collozoum armatum*, Haswell. A single zooid in optical section. x 450.
- Fig. 2. *Collozoum alpha*. A portion of the colony shewing one of the ordinary zooids and one of the masses of granule-like bodies supposed to be microspores. x 450.
- Fig. 3. *Collozoum ovale*, Haswell. A single zooid. x 300.
- Fig. 4. *Collozoum arcuatum*, Haswell. A single zooid with the peculiarly modified *Xanthellæ*. The oil-globule has been here rendered black. The amorphous pigmented masses within the capsule are not represented. x 450.
- Figs. 4A, 4B, 4C. *Xanthellæ* of *Collozoum arcuatum*. x 900.
- Fig. 5. *Collozoum beta*. A single zooid in optical section, showing the layer of minute bodies superficial to the capsular-membrane. x 300.
- Fig. 6. *Collosphæra hedleyi*, Haswell. Test of a zooid. x 300.
- Fig. 7. *Collosphæra uniforis*, Haswell. Test. x 300.

