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On some New and Interesting Foraminifera from the Funafuti Atoll, Ellice Islands. By FREDERICK CHAPMAN, A.L.S., F.R.M.S.

[Read 21st December, 1899.] *

(PLATES 1–4.)

THE expeditions dispatched by the Royal Society of London from New South Wales under the direction of Professor W. J. Sollas, and of Professor T. Edgeworth David, for the purpose of making a boring in a typical atoll in the Pacific Ocean, have furnished zoologists and others with some very interesting material for detailed study. In the examination of this material and that of other coral-reefs, one cannot fail to be impressed by the importance of organisms other than corals in forming the great mass of the reef.

Among the groups of organisms which are as active as coral, and even more so, in building up the enormous banks, mounds, and reefs of limestone in coral areas, we may mention the calcareous algæ *Halimeda* and *Lithothamnion* as prominent rock-formers; the first-named often growing in the greatest profusion to the exclusion of almost all else, especially in the lagoon, whilst the latter grows in branching masses which entangle smaller organisms and loose sand, or encrust corals and millepores, often at a considerable depth. A laminated alga allied to *Lithothamnion* is also found growing in nodular form in alternate concentric layers with the foraminifer *Polytrema*; and the condition favourable for this peculiar intergrowth seems to be a sandy area influenced by strong currents. At the surface on the Funafuti Atoll, these nodular intergrowths were found only on the seaward face of the reef.

[* This paper has been unavoidably delayed in publication.—ED.]

The Foraminifera, however, constitute the greater proportion of the enormous deposits of sand associated with the reef formation, and which speedily become consolidated into limestone-rock through the chemical changes which so readily take place therein. The most important genera of the Foraminifera which were found in these coral deposits, taken in the relative order of their abundance, are *Amphistegina*, *Heterostegina*, *Polytrema*, *Tinoporus*, *Orbitolites*, *Carpenteria*, *Gypsina*, *Calcarina*, and *Miliolina*. The three first-named are found commonly throughout the material of the reef-boring, in sand and rock alike, always retaining some part of their original structure; by this they can easily be recognized, although the matrix of the rock may have undergone the most marked changes. In the deeper parts of the Atoll-boring, other genera may have been present, for fragments of *Tinoporus* in various stages of decay were seen down to 245 feet, and *Calcarina* to 274 feet from the surface.

Among other active agents in the building of the limestone-reefs may be mentioned the Alcyonarians, Echinoderms, Serpulæ, and the Mollusca.

Through the kindness of Professor Judd, C.B., and the Coral-Reef Committee of the Royal Society, I have been favoured with the opportunity for thoroughly examining, in respect to the group of the Foraminifera, the whole of the materials obtained by the expeditions to Funafuti, which had been sent to the Royal College of Science, London.

The numerous samples from Funafuti have in most cases now been examined, but to do justice to so large a quantity of material some further work is requisite, and it is therefore considered advisable to publish this paper as a first instalment, which deals with the more prominent or larger forms, especially those found adherent to the coral or encrusting other organisms, and intergrowing with them. These larger forms of the Foraminifera do not seem to have received the notice they deserve, for they often constitute a considerable bulk of the consolidated reef, and are rock-builders in the truest sense of the term. That they are often overlooked is due to the fact that they more frequently occur on the rough and encrusted pieces of reef-rock, which are not so systematically collected, probably owing to their presenting little in the way of attractive specimens of corals and other more or less prominent organic remains.

Whilst describing these species of Foraminifera the occasion

is taken to include an account of several new forms; but this does not exhaust the collection in hand, which it is hoped will furnish interesting material for further papers on the same group of animals.

The localities at Funafuti are given in their relative positions around the atoll from N. E. S. to W.

FORAMINIFERA.

Family MILIOLIDÆ.

Subfamily PENEROPLIDINÆ.

PENEROPLIS, *Montfort* [1808].

Subgenus novum MONALYSIDIUM.

Remarks on the Subgenus.—Test porcellanous, shell-wall very thin; surface usually covered with minute tubercles, sometimes smooth or highly polished and with vertical rows of puncta (not perforations). Segments sub-globose, flattened or elongate, at first arranged in a spiral, afterwards rectilinear. Aperture simple, either a circular inverted orifice or an everted phialine termination.

This subgenus is intended to comprise the long delicate crosier-shaped specimens of which "*Nautilus lituus*," Gmelin, is the type.

These particular forms were represented in the 'Challenger' collections by imperfect specimens, described by Dr. H. B. Brady under the generic name *Peneroplis*. The Funafuti material has yielded some good examples of these forms; and in the light of these it now appears convenient to distinguish the specimens subgenerically at least, on account of their dimorphic character *, and especially since their apertures differ from the typical cribrate or dendriform orifice of *Peneroplis* proper, or *Spirolina*, and are similar to *Nodosaria* or *Sagrina* of the hyaline group.

It is possible that d'Orbigny's *Nodosaria punctata* † is a fragment of one of the tuberculate forms of *Monalysidium*.

PENEROPLIS (MONALYSIDIUM) SOLLASI, subgen. et sp. nov. (Pl. 1. fig. 6.)

Test consisting of a flat coil of sub-oval segments, which afterwards become a straight series with subglobular or slightly compressed chambers. Terminal orifice with a neat everted

* In the sense employed by Prof. Kitchen Parker.

† See 'Foraminifères' in Sagra's Hist. Cuba, 1839, p. 14, pl. 1. figs. 4, 5.

margin. Surface of test covered with minute tubercles which under a low power resemble perforations. Length $\frac{1}{45}$ inch (·52 mm.).

The fragmentary specimens recorded and figured by H. B. Brady * are tuberculate similarly to the above species, but differ considerably in the shape of the chambers and in showing a strong partitional septum on the surface between each segment.

Found in sand from the beach, Avalau Id. (South Id.), Funafuti. Coll. by Prof. Sollas.

PENEROPLIS (MONALYSIDIUM) POLITA, sp. nov. (Pl. 1. fig. 5.)

Test imperfect but probably similar in general outline to the foregoing species, with the exception that the segments, especially of the last part of the series, are more irregular in form. The rectilinear portion of the shell (the only part discovered at present) consists of six segments, subcylindrical and irregular; shell-surface highly polished, with vertical rows of minute puncta on each segment, and white. Aperture with an everted margin. Length of portion found $\frac{1}{35}$ inch (·714 mm.).

From the beach-sand, Avalau Id. (South Id.), Funafuti. Coll. by Prof. Sollas.

Family ASTRORHIZIDÆ.

Subfamily RHABDAMMININÆ.

SAGENINA (nom. emend.)†.

(Sagenella, *Brady* [1879].)

SAGENINA FRONDESCENS (*Brady*). (Pl. 1. figs. 1, 2; Pl. 2. figs. 1, 2.)

Sagenella frondescens, Brady, 1879, Quart. Journ. Micr. Sci. vol. xix. p. 41, pl. v. fig. 1; Bütschli, 1880, in Bronn, Klassen etc. Thier-Reichs, p. 195, pl. v. fig. 16; Brady, 1884, Report 'Challenger,' vol. ix. p. 278, pl. xxviii. figs. 14 & 15.

Nothing has been done towards extending the somewhat limited range of distribution for this species since Brady described "this singular little organism from the South Pacific." The original localities were the Admiralty Islands, where it was found on calcareous plants and fragments of shells at 16–35 fathoms; and

* Report 'Challenger,' 1884, vol. ix. pl. xiii. figs. 24 & 25.

† *Sagenina* is here suggested for *Sagenella*, which name has been previously bestowed on a genus of the Polyzoa. See Hall's Nat. Hist. N. York, 1852, vol. ii. p. 172, pl. 40 E. figs. 6 *a*, *b*.

off Tongatabu, Friendly Islands, at 18 fathoms. Brady states that the specimens from the latter locality lack distinctive characters; those around Funafuti, not so greatly distant, being in first-rate preservation, may serve to strengthen his identification. Some of the specimens from the Funafuti lagoon found attached to the surface of *Halimeda*-joints are extremely fine and characteristic.

Seeing Dr. Hæckel's statement with regard to the apparently dubious character of some *Astrorhizidæ*, especially *Rhabdammina*, *Rhizammina*, *Sagenella*, etc., that they "may also belong to the arenaceous Keratosa (*Ammoconidæ*)," I have carefully examined the composition of the test of *Sagenina* (*Sagenella*), with the result that there appears sufficient evidence in support of the view taken by Dr. Brady as to its rhizopodal nature. Sections of a *Halimeda*-joint with *Sagenina* attached have been made in a vertical direction; also the test itself has been isolated. These were examined under a high power, and showed this organism to have a finely arenaceous to subchitinous test (that is to say, where finely divided material is wanting, a thin chitinous tube is the result) traversed by minute inosculating canals such as are seen in the other arenaceous rhizopods.

Hæckel describes a form of the Keratosa, namely *Ammoconia sagenella* *, with regard to which he says: "Very similar to this latter, or even identical with it, may be that form which Brady has figured as *Sagenella frondescens*." In the description of the species, however, the diameter of the separate branchlets is given as 1–2 mm. The average diameter (and it varies but little) of the branchlets of *Sagenina frondescens* is ·5 mm. Further, the example of *Ammoconia* figured in the Report is quite unlike *Sagenina* in consisting of a meshwork of tubes standing erect, instead of being adherent at every point. The general finish of the tubes of *Sagenina*, especially at the terminal or apertural points, enables one to see the affinity of this form with other well-known rhizopods, both arenaceous and hyaline, as *Webbina* and the adherent *Ramulina cervicornis*. In one part of the transparent test which I have examined, there is a curious stellate structure reminding one of the fused spiculose base seen in the tissues of Alcyonarians. There is not sufficient evidence, however, to lead one to form any definite conclusion from this peculiarity of structure.

* Report 'Challenger,' vol. xxxii. pp. 30 & 31, pl. viii. figs. 5 A, 5 B.

Sagenina frondescens is a well-distributed organism around Funafuti and in the lagoon. In places it is quite abundant. In the dredgings made by Prof. David and Mr. Finckh this species was found as follows:—

N. of Pava, 36 fathoms.

Funamanu (Beacon Id.), 150 fathoms; very fine examples.

Tutanga, 200 fathoms (Halligan and Finckh Coll.), occasional.

S. of Funafuti, 30–120 fathoms.

"To" S. of Funafuti, 60 fathoms, common on *Cycloclypeus* and *Halimeda*.

In the lagoon boring it was found at the surface of the lagoon-floor; very rare.

At 21½ feet below floor; very common, and fine examples.

At 50 feet; frequent.

At 62 feet; common.

At 81½ feet; very rare.

Family LITUOLIDÆ.

Subfamily LITUOLINÆ.

HADDONIA, *Chapman* [1898].

HADDONIA TORRESIENSIS, *Chapman*.

Haddonia Torresiensis, Chapman, 1898, Journ. (Zool.) Linn. Soc. Lond. vol. xxvi. p. 452, pl. xxviii. figs. 1–5 and woodcut p. 453.

This interesting genus, although but lately discovered in material from Torres Strait, has already been found in great abundance both around Funafuti and in the lagoon.

The large series of specimens now before us shows to some extent the great variety of forms exhibited by this organism. In the first stages of its growth *Haddonia* is depressed and repent, having a coiled series at the commencement or a simple linear-shaped arrangement of segments; in the latter case it somewhat resembles *Bdelloidina*, to which it probably bears some relationship. The test afterwards grows off the surface of attachment, still retaining its *point d' appui*, often continuing in a very erratic line of growth, and sometimes forming several bends and twists nearly at right angles, in one instance curiously resembling a larva of the Geometrine Lepidoptera when feeling the air for a fresh foothold.

The largest specimen met with measures over $\frac{5}{8}$ inch (about 16 mm.) in length, and was only slightly attached by the aboral end, coming away in the dredge. The organism has

secondarily attached itself a little beyond the middle of the test to an echinoderm spine. This specimen came from Funamanu Id. (Beacon Id.) at 150 fathoms. *H. Torresiensis* was also found in the material from the boring in the lagoon at Funafuti. The specimens are of average size.

In the dredgings made by Prof. David and Mr. Finckh, I have found *H. Torresiensis* as follows :—

N. of Pava, 35 fathoms ; a young individual.

Funamanu Id. (Beacon Id.), 150 fathoms ; the large specimen previously mentioned.

Tutanga, 200 fathoms (dredged by Messrs. Halligan and Finckh); rather small examples.

S. of Fuafatu, 25 fathoms ; a young individual.

S. of Fuafatu, 60 fathoms; a young example attached to *Cycloclypeus Carpenteri* (form B).

S. of Fuafatu, 30–120 fathoms ; a much contorted example.

S. of Fuafatu, 119 fathoms ; very common on a fragment of Millepore.

"To" S. of Fuafatu, 40 fathoms, bottom fairly hard ; a neat specimen torn off the rock.

"To" S. of Fuafatu, 60 fathoms ; a neat specimen.

S.S.W. of Fuafutu, 60 fathoms ; common on coral rocks.

Two specimens were also obtained from the lagoon-boring at $35\frac{1}{2}$ feet and at $81\frac{1}{2}$ feet below the lagoon-floor.

Bdelloidina, *Carter* [1877].

Bdelloidina aggregata, *Carter*. (Pl. 1. fig. 3, and fig. in text.)

Bdelloidina aggregata, Carter, 1877, Ann. Mag. Nat. Hist. ser. 4, vol. xix. p. 201, pl. xiii. figs. 1–8 ; Brady, 1884, Report 'Challenger,' vol. ix. p. 319, pl. xxxvi. figs. 4–6.

"Test adherent, depressed ; consisting of a number of closely-approximated chambers, arranged more or less regularly in a single, simple or branched, linear series, and intercommunicating by a row of pools on each septal face. Segments very short (on the axis of growth) and broad ; curved or irregular in outline; subdivided more or less completely by numerous secondary septa. Walls rough externally, interior surface smooth. Aperture porous. Diameter of the adherent patches $\frac{1}{6}$ inch (4 mm.) or more." *

The above species was well and minutely described by

* Brady, *op. cit.* pp. 319, 320.

Mr. Carter, who drew attention to the porous nature of the shell-wall in this and some other Rhizopods.*

With regard to the porosity of the shell-wall, it appears to me that Carter conclusively demonstrated the presence of pores in the wall of the test, and although these pores are not regular enough to be denominated tubules, yet they probably serve the same purpose for the sarcodic body. Dr. Brady has suggested that the puncta on the internal surface of *Bdelloidina* may be only superficial depressions. In corroboration of Carter's original idea, it is worth noting a precisely similar structure in the shell-wall of the allied genus *Haddonia*, in which the test is stronger and more inflated, and the structure of the shell-wall greatly emphasized. There the porosity of the shell-wall seems to exist beyond question.

The apertural pores at the distal end in *Bdelloidina* are evidently the terminations of the labyrinthular canals seen in the interior of the shell.

The width of the test is usually $\frac{1}{6}$ inch (about 4 mm.) and the length slightly more. One example from Fuafatu, however, measures as much as $\frac{1}{2}$ inch (12·5 mm.).

Bdelloidina is a genus likely to be overlooked, since its habit is to seek shelter in hollows of shells and coral-rock, creeping over the interior and filling up irregularities in the surface. Its usual colour, moreover, is that of a calcareous sand, for it is composed of little granules (fragments of organisms) or even minute shells, together with occasional sponge-spicules. This fact probably explains its rarity in records of foraminiferal faunas from coral areas.

The only localized specimens of *Bdelloidina aggregata* previously obtained were from the 'Challenger' dredgings in shallow water near the Admiralty Islands on the north coast of Papua, generally adherent to molluscan shells.

A fossil specimen has been recorded as adherent to a Cretaceous Ammonite from Mr. Matthew Wright's cabinet †; a drawing of this was made many years ago which is in the possession of Prof. Rupert Jones. I am enabled by the kindness of Prof. Jones to give a reproduction of this drawing for the first time. (See fig. 1, p. 9.)

In the neighbourhood of Funafuti *Bdelloidina aggregata* is notably restricted to shallow water.

* Carter, *op. cit.* pp. 202–208.

† See Brady, Rep. Chall. 1884, vol. ix. p. 320.

Near Pava Id., fairly numerous on fragments of Millepore at 63 fathoms.

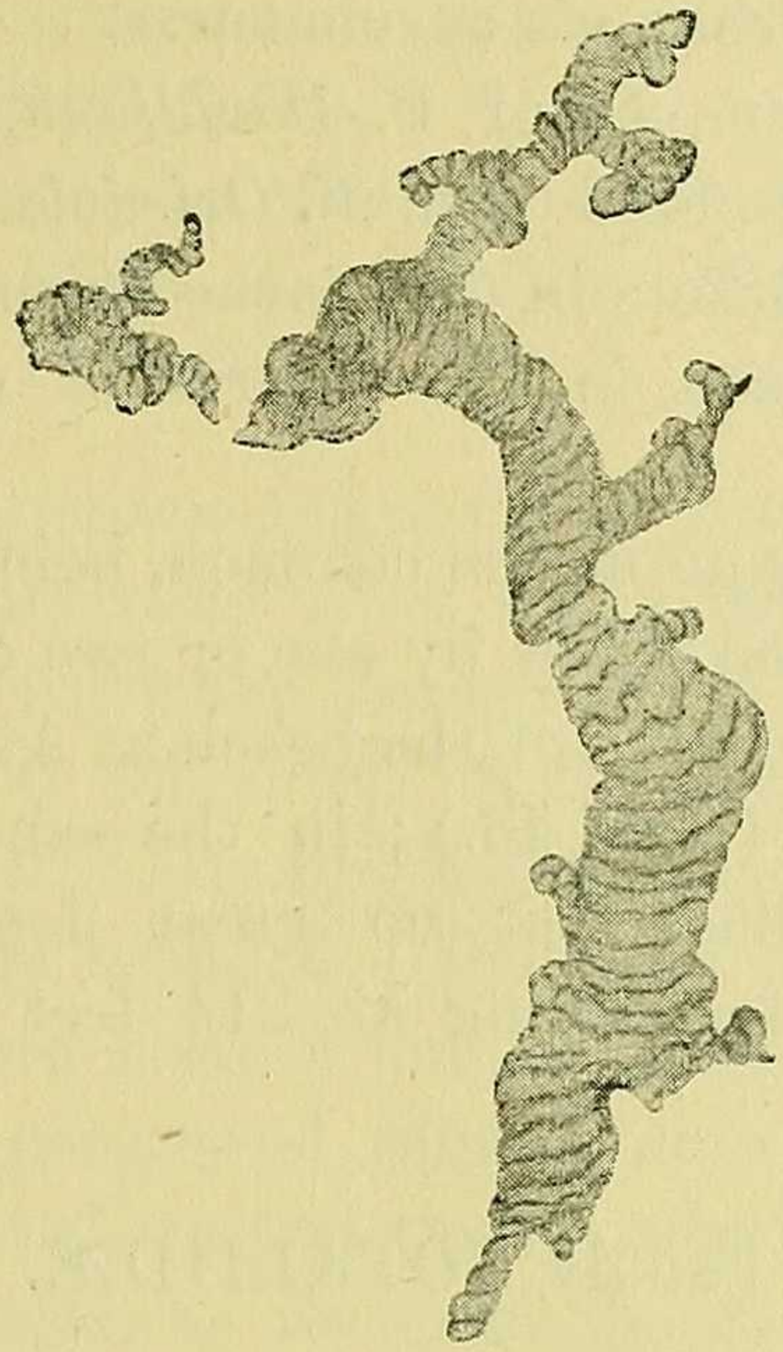

Fig. 1.—*Bdelloidina aggregata*, Carter from the Chalk of Kent. (From a drawing lent by Prof Rupert Jones of a specimen in the Collection of the late Matthew Wright.)

Funamanu Id. (Beacon Id.), on *Turbinaria*, 50 fathoms (dredged by Prof. David and Mr. Finckh).

S. of Fuafatu Id., in the interior of molluscan shells, 25 fathoms.

"To" S. of Fuafatu Id., 60 fathoms.

Family TEXTULARIIDÆ.

Subfamily TEXTULARIINÆ.

VALVULINA, *d'Orbigny* [1826].

VALVULINA DAVIDIANA, sp. nov. (Pl. 1. fig. 4.)

Test triangular, chambers triserially arranged and forming a more or less equilateral cone; aperture situated in a sub-crescentic depression, with a tooth-like valve projecting across, and sometimes a secondary cne nearly meeting from the opposite side. Texture somewhat coarsely arenaceous, composed of calcareous particles; colour white to pale cream. Length $\frac{1}{25}$ inch (1 mm.).

The above species belongs to the same type as d'Orbigny's *Valvulina triangularis* from the Tertiary beds of the Paris Basin *. The specimens from Funafuti differ, however, in having

* Ann. Sci. Nat., vol. vii. 1826, p. 270, No. 1; Modèles, No. 25.

a more decidedly triangular and elongate test, and the oral end less inflated. The valve is more usually tooth-like, rather than a simple flap as in d'Orbigny's specimens.

The elongated examples of *V. Davidiana*, which by the way are rare, may be compared with *V. Oviedoiana* of d'Orbigny*; the latter, however, differs in the marked concavity of the face of each segment, as seen in the figures of d'Orbigny's Cuban specimens.

V. Davidiana is by no means common, being represented in all the samples mentioned below by one or two examples at most.

It was found in the sand of the beach at Avalau Id. (South Id.) and at Fualopa Id. (Gold Id.); in the sand pumped up from the 1st boring (Sollas) "at no great depth"; and it also occurred in the lagoon boring at $21\frac{1}{2}$ feet below the lagoon-floor.

Family ROTALIIDÆ.

Subfamily SPIRILLININÆ.

SPIRILLINA, *Ehrenberg* [1841].

SPIRILLINA SPINIGERA, sp. nov. (Pl. 1. figs. 7 *a–c*.)

Test free, but perhaps at one time adherent or resting generally on one face, discoidal, consisting of a single tube in four convolutions. The two sides unequal, the broader or basal face concave, having the primordial or central portion globulose and armed with a short blunt spine which does not project beyond the general surface; around the periphery other blunt spines are arranged, to the number of fourteen or more, and the salient edges of the coils are more or less spinose. The upper (smaller) face is slightly convex and tolerably smooth. The terminal portion of the coil is separated from the rest of the shell and is slightly reverted. Diameter of test $\frac{1}{77}$ inch (·325 mm.).

In having the lateral faces of unequal size this form resembles *Spirillina inæqualis*, Brady †.

It also shows some affinity towards *S. tuberculata*, Brady ‡, in its separated termination.

The form may have been derived directly from *S. limbata* var.

* Foram. Cuba, 1839, p. 103, pl. ii. figs. 21, 22 (*V. Oviedoana* on plate).

† Quart. Journ. Micr. Sci. vol. xix. n. s. (1879), p. 278, pl. viii. figs. 25 *a*, *b*.

‡ Ibid. p. 279, pl. viii. figs. 28 *a*, *b*.

denticulata, Brady *, by the redundant outgrowth of the transverse bars or denticulæ, but this is merely a suggestion.

From beach-sand, Avalau Id. (South Island), Funafuti; very rare. Collected by Prof. Sollas.

Also from the boring in the lagoon at Funafuti at 62 feet below the floor of the lagoon (163 feet below low-water spring tides); very rare.

SPIRILLINA TUBERCULATO-LIMBATA, sp. nov. (Pl. 1. figs. 8 *a–c*.)

Test discoidal, consisting of a single tube with about six convolutions. The larger and flat surface is limbate and has the peripheral edge of the coil sharp on that side; the smaller face is slightly rounded and strongly tuberculate. The upper part of the peripheral edge rounded. Diameter $\frac{1}{50}$ inch (·5 mm.).

The dissimilar faces remind one of *S. inæqualis*, Brady, but in that species the peripheral edge is blunt or square and the smaller face is not so characteristically tuberculate.

S. tuberculato-limbata, as its name implies, combines in one form the characters of two of Brady's species, *S. tuberculata* † and *S. limbata* ‡.

This species was found at the depth of 40 feet in the 2nd boring at Funafuti (Sollas Coll. 1896), where it was common.

It has occurred sparingly at the depths of 65 and 70 feet in the deep boring at Funafuti (David Coll. 1897). Also in dredgings N. of Pava, 36 fathoms (David Coll. 1898).

Subfamily ROTALIINÆ.

DISCORBINA, *Parker & Jones* [1862].

DISCORBINA TUBEROCAPITATA, sp. nov. (Pl. 1. figs. 9 *a–c*.)

The superior aspect roughly conical, the apex swollen into a ball-like prominence; two convolutions of the shell are visible on the apex. The inferior surface is flat or slightly concave, and exhibits five chambers; in the area round the umbilical depression the surface of the shell is granulate. The peripheral edge has a thin and narrow flange. Shell translucent and of a pale opalescent blue colour. Diameter $\frac{1}{72}$ inch (·347 mm.).

* Rep. Chall. vol. ix. 1884, p. 632, pl. lxxxv. fig. 17.

† Quart. Journ. Micr. Sci. vol. xix. n. s. 1879, p. 279, pl. viii. figs. 28 *a*, *b*; Rep. Chall. vol. ix. 1884, p. 631, pl. lxxxv. figs. 12–16.

‡ Quart. Journ. Micr. Sci. vol. xix. n. s. 1879, p. 278, pl. viii. figs. 26 *a*, *b*; Rep. Chall. vol. ix. 1884, p. 632, pl. lxxxv. figs. 18–21.

This curious little species is quite distinct from the other forms of *Discorbina* found at Funafuti. It appears to have had its origin in a form similar to *D. pileolus*, d'Orbigny *, which it somewhat resembles in the conical portion—a form common in the shallow waters of the Pacific.

D. tuberocapitata is rare, and has occurred in two samples as far as they have been at present examined. In the deep boring at Funafuti (David, 1897) at a depth of 65 feet; and in the lagoon-boring at 50 feet below the floor of the lagoon.

Carpenteria, *Gray* [1858].

Carpenteria utricularis, *Carter*. (Pl. 2. fig. 4; Pl. 4. figs. 3, 4.)

Polytrema utriculare, Carter, 1876, Ann. Mag. Nat. Hist. ser. 4, vol. xvii. p. 210, pl. xiii. figs. 11–16.

Carpenteria utricularis, Carter, 1877, Ann. Mag. Nat. Hist. ser. 4, vol. xx. p. 176; Brady, 1884, Report 'Challenger,' vol. ix. p. 678, pl. xcix. figs. 6, 7, pl. c. figs. 1–4; Egger, 1893, Abhandl. bayer. Akad. Wiss., math.-phys. Cl. ii. vol. xviii., Abth. ii. p. 246, pl. xxi. fig. 18.

The chief characteristics of this species are the strongly inflated segments, the occasional plurality of apertures (basal as well as terminal), and the coarsely reticulated structure of the walls of the test. In sections the shell-wall is seen to have a papillate (rugose) external surface. The colour of *C. utricularis* in the Funafuti specimens is sometimes brown or ash-grey, but generally speaking the specimens are of a vivid apple-green tint, probably due to the presence of a symbiotic alga in the coarse structure of the test. The apertural portion of the shell is often prolonged into a slender salient tube.

C. utricularis is apparently the commonest form of *Carpenteria* dredged at Funafuti.

This species has been recorded from the Pacific, Cape Verde Islands, the West African coast, the Mauritius, and the West Indies. Brady records it at depths ranging from 16 to 350 fathoms. In the samples collected round Funafuti by Prof. David and Mr. Finckh, I have found *C. utricularis* in the following:—

North of Pava, 57 fathoms, on a gorgonid and a millepore.

* *Valvulina pileolus*, Voyage Amér. Mérid. 1839, vol. v. pt. 5: "Foraminifères," p. 47, pl. i. figs. 15–17.

Discorbina pileolus (d'Orbigny), Brady, Rep. Chall. vol. ix. 1884, p. 649, pl. lxxxix. figs. 2–4.

Funamanu Id. (Beacon Id.), 50 fathoms.

Funamanu Id. (Beacon Id.), 80 fathoms; a specimen of bright green colour attached to a gorgonid.

Off Funamanu Id. (Beacon Id.), 150 fathoms; a specimen attached to *Halimeda*.

Tutanga, 94 fathoms; the largest specimen found, measuring nearly half an inch at the base. This is attached to a cylindrical millepore.

Near Tutanga, 136 fathoms.

S. of Fuafatu, 60 fathoms; on *Cycloclypeus Carpenteri*.

S.S.W. of Fuafatu, 60 fathoms; very abundant on a large coral fragment.

S. of Fuafatu, 25 fathoms. (A depressed form very near one of Gray's figures of *C. balaniformis*.)

A single specimen of *C. utricularis* was also found in the sand pumped up (at no great depth) from the 1st boring (Sollas Coll.). In the deep boring (David Coll.) this species was found at 65 feet and at 70 feet.

CARPENTERIA BALANIFORMIS, *Gray*. (Pl. 4. figs. 1, 2.)

Carpenteria balaniformis, Gray, 1858, Proc. Zool. Soc. Lond. vol. xxvi. p. 269, figs. 1–4.

Carpenteria, Carpenter, 1862, Introd. Foram. pl. xxi. figs. 6–14.

C. balaniformis, Gray, Rupert Jones, 1875, in Griffith and Henfrey's Micrographic Dictionary, 3rd ed., vol. ii. pl. 42. fig. 28.

C. balaniformis, Gray, Carter, 1877, Ann. Mag. Nat. Hist. ser. 4, vol. xix. pl. xiii. fig. 13.

"*Carpenteria* young specimens, *C. balaniformis*?," Brady, 1884, Report 'Challenger,' vol. ix. p. 677, pl. xcviii. figs. 14, 17.

C. balaniformis, Gray, Agassiz, 1888, Three Cruises 'Blake,' vol. ii. p. 168, fig. 514.

C. balaniformis, Gray [non Brady], Egger, 1893, Abhandl. bayer. Akad. Wiss., math.-phys. Cl. ii. vol. xviii., Abth. ii. p. 246, pl. xxi. figs. 13–15.

The specific characters of *C. balaniformis* are perhaps difficult to define, since the original specimens of Gray appear to possess some of the characters of both *C. monticularis* and *C. utricularis*, Carter. However, the name may be retained for the small, balaniform, depressed, conical and usually smooth *Carpenteriæ* often found clustering upon the stems of gorgonids and other objects of attachment, where the currents have more or less access to them.

Egger's specimens were dredged off the coast of West Africa. Examples, which may be taken as typical of the species, were

found round Funafuti in a dredging made between 115 and 200 fathoms. They are attached to corals as *Synhelia*? and *Caryophyllia*?, and to a mass of *Serpula*-tubes; on the latter they occur in great abundance (David Coll.).

It also occurs in dredgings made by Messrs. Halligan and Finckh at Tutanga, 200 fathoms. *C. balaniformis* was also found in sand from the bore-hole, Funafuti, at 75 feet; rare (David Coll.).

CARPENTERIA MONTICULARIS, *Carter*. (Pl. 2. fig. 5; Pl. 4. figs. 5, 6.)

Carpenteria, Carpenter, 1862, Introd. Foram. pl. xxi. fig. 7.

Carpenteria monticularis, Carter, 1877, Ann. Mag. Nat. Hist. ser. 4, vol. xix. p. 211, pl. xiii. figs. 9–12; idem, ibid., ser. 4, vol. xx. p. 68, and woodcut; Brady, 1884, Report 'Challenger,' vol. ix. p. 677, pl. xcix. figs. 1–5; Egger, 1893, Abhandl. bayer. Akad. Wiss., math.-phys. Cl. ii. vol. xviii., Abth. ii. p. 246, pl. xxi. fig. 12.

This species, although so well-known, does not appear to have been found in any great abundance in the localities from which it has been previously recorded. The exceptionally fine specimens figured by Brady came from Zamboanga, Philippine Islands, at 102 fathoms; and he also records it from nine other localities, chiefly in the Pacific and Indian Oceans, at depths varying from 40 to 1035 fathoms, and at the same time notes that these specimens are "for the most part of small size and not so well characterized."

Egger obtained this species from the coast of West Africa and the Mauritius.

The test of this species is of considerable thickness, with smooth surfaces, unlike *C. utricularis*, and the fine tubuli are here and there relieved by coarser tubules, running parallel with them.

The Funafuti specimens are in nearly all examples of a delicate yellowish- or salmon-pink tint. One specimen is coloured a delicate mauve.

In the dredgings made by Prof. David and Mr. Finckh around Funafuti, I have found *C. monticularis* in the following:—

Funamanu Id. (Beacon Id.), 80 fathoms; one specimen.

Tutanga, 86 fathoms; one specimen.

Tutanga, 135 fathoms; one specimen attached to a molluscan shell.

Tutanga, 200 fathoms.

S.S.W. of Fuafatu, 60 fathoms; one specimen.

In the collections made by Prof. Sollas at Funafuti *C. monticularis* has occurred in :—

Beach sand, Gold Island; one specimen.

Beach of Creek, Rocky Island; one specimen.

In coral-rock of the 2nd shaft, trial pit, ocean side; frequent.

Under solid platform, seaward face, 3rd shaft, trial pit; common.

In sand at 90 feet in the 1st (Sollas's) boring; one specimen.

The fragmentary tests of this species also occur in great abundance in some of the thin slices of the core from the deep boring at Funafuti carried out by Prof. Edgeworth David. The remains of this species sometimes constitute quite an appreciable amount of the rock.

Calcarina, *d'Orbigny* [1826].

Calcarina hispida, *Brady*, var. pulchella, nov. (Pl. 1. fig. 10.)

"*Calcarina* distinguished by unusual exuberance of spinous outgrowths," Carpenter, 1862, Introd. Foram. p. 217, figs. xxxiii A & B, figs. xxxiv D, E, F, G.

Many of the specimens of *C. hispida* from Funafuti differ considerably from Brady's type-specimens *. The shell-wall is more delicate, and the spurs are slenderer, with exuberant outgrowths at the extremities, whilst they are decorated with longer spines than usual. This variation gives to the test a light plumose appearance. In point of size the variety equals the type. The specimens which Dr. Carpenter figured were from the Philippines.

C. hispida var. *pulchella* occurs with frequency both in the Beach Sand, "South Island" (Avalau Islet), and in the 1st boring at Funafuti, "at no great depth" (Sollas, 1896).

Subfamily Tinoporinæ.

Polytrema, *Risso* [1826].

[The members of this genus are often so like minute branching corals and polyzoa, and in one instance resembling externally certain calcareous algæ, that even at the present time they may

* *Calcarina hispida*, Brady, 1876, Proc. R. Irish Acad. ser. 2, vol. ii. p. 590.

C. calcar, d'Orb., var. *hispida*, Brady, Carter, 1880, Ann. Mag. Nat. Hist. ser. 5, vol. vi. p. 453.

C. hispida, Brady, 1884, Rep. Chall. vol. ix. p. 713, pl. cviii. figs. 8, 9.

at first sight be referred to the above groups by those who are not intimately acquainted with the minute structure of these Rhizopods. *Polytrema miniaceum* and its varieties are extremely ubiquitous at Funafuti.]

POLYTREMA MINIACEUM (*Pallas*). (Pl. 4. fig. 7.)

Millepora miniacea, Pallas, 1766, Elenchus Zoophytorum, p. 251 Linné, 1788, Systema Nat., 13th (Gmelin's) ed. vol. i. pt. 6, p. 3784, no. 6; Esper, 1791, Die Pflanzenthiere, pt. i. p. 225, pl. xvii. figs. 1–4.

M. rubra, Lamarck, 1816, Anim. sans Vertèbres, vol. ii. p. 202.

Polytrema corallina, Risso, 1826, Hist. Nat. Europ. Mérid. vol. v. p. 340, no. 19.

P. miniaceum (Esper), Defrance, 1816–1830, Dict. Sci. Nat. Atlas, Zooph. pl. xliv. figs. 4, 4 *a*; Blainville, 1826, Dict. Sci. Nat. vol. xlii., Atlas Zooph. vol. i. p. 17; idem, 1834, Actinologie, pp. 410, 673, pl. lxix. figs. 4, 4 *a*.

P. rubra (Lam.), Dujardin, 1841, Hist. Nat. Zooph. Infus. p. 259.

Pustularia rosea, Gray, 1858, Proc. Zool. Soc. Lond. vol. xxvi. p. 271.

Polytrema rubra (Lam.), Carpenter, 1862, Introd. Foram. p. 235, pl. xiii. figs. 18–20.

P. miniaceum (Linné), Schultze, 1863, Wiegmann's Archiv, p. 81, pl. viii.; Allman, 1870, Ann. Mag. Nat. Hist. ser. 4, vol. v. p. 372.

P. miniaceum, Blainville, Carter, 1876, Ann. Mag. Nat. Hist. ser. 4, vol. xvii. p. 185, pl. xiii. figs. 1–6.

P. rubra (Lam.), Schwager, 1877, Boll. R. Com. Geol. Ital. vol. viii. p. 26, pl. 72.

P. miniaceum, Blainville, Möbius, 1880, Beitr. Meeresfauna Insel Mauritius etc. p. 85, pl. vii. figs. 1–17; Bütschli, 1880, in Bronn, Klassen etc. Thier-Reichs, p. 208, pl. ix. fig. 11.

P. miniaceum (Linné), Brady, 1884, Rep. Chall. vol. ix. p. 721, pl. c. figs. 5–9, pl. ci. fig. 1; Agassiz, 1888, Three Cruises 'Blake,' pt. ii. p. 169, fig. 519; Egger, 1893, Abhandl. bayer. Akad. Wiss., math.-phys. Cl. ii. vol. xviii., Abth. ii. p. 437, pl. xxi. figs. 1, 2, 16, 17; Goës, 1896, Bull. Mus. Comp. Zool. vol. xxix. no. 1, Memoir xx. p. 75

P. miniaceum occurs in the samples both from the lagoon and the outer part of the reef at Funafuti, as well as from the deeper soundings round about, down to 200 fms. The species is not so common in the lagoon as it is outside the reef, but nevertheless some very fine specimens have been noticed from the lagoon-deposits.

In all cases the specimens were originally attached to some object for basal support; and it is noteworthy that the kind of support has greatly determined the mode of habit of the form, and hence its variations. Where the organism has sufficient space and freedom around its base, the delicate arborescent form

is the result. Should it become cramped in its surroundings, the rhizopod makes a thick base with short and strong prolongations. When the *Polytrema* affixes itself to a detached fragment affected by currents which roll it over, the organism forms a thin encrustation, which in many cases is in turn encrusted by a *Lithothamnion*, then again by *Polytrema*, and so on, until the nodules often measure as much as 5 centimetres in diameter. This latter mode of growth in *Polytrema* has hitherto been unnoticed, and seems to merit a distinct varietal name *. An intermediate stage between this encrusting *Polytrema* and the arborescent typical form is represented by Carter's *P. mesentericum* †.

The red colour of *Polytrema* is apparently very little, if at all, dependent upon the influence of light. Some of the finest coloured specimens occur at considerable depths, and it is remarkable that off Funamanu Id. (Beacon Island), at a depth of 150 fathoms, *Polytremata* of the deepest and richest colour were found.

Although commonly found in shallower water, *P. miniaceum* has been recorded in the 'Challenger' soundings from a depth as great as 1000 fathoms. Egger found it ranging down to a depth of 411 metres (224 fathoms) near Mauritius. Specimens recorded from the Caribbean Sea by Goës were found at 115 fathoms.

POLYTREMA MINIACEUM (*Pallas*), var. INVOLVA, nov. (Pl. 2. fig. 3, & text-fig. 2.)

Test consisting of a rudely parallel series of acervuline chamberlets disposed round a nucleus, or partly encrusting an adventitious particle. The organism in this stage shows little tendency to send forth prolongations, but seems content with forming mere rounded prominences or papillæ at intervals on the surface of growth. This variety often shows a remarkable tendency to alternate in its growth with layers of *Lithothamnion*, thus building up nodular masses of a composite nature ‡. The nodules sometimes reach the dimension of 5 centimetres.

As previously noticed, the form named *Polytrema mesentericum*, Carter, may be in part comparable with this form. It is probable, however, that this was the basal portion of a large

* See p. 1.

† Ann. Mag. Nat. Hist. ser. 5, vol. v. (1880) p. 444, pl. xviii. figs. 3 *a–h*.

‡ Another species has been noticed at Funafuti which occurs in the limestones alternating in its growth with *Lithothamnion*, namely *Gypsina inhærens* (Schultze); but it does not form anything like so complete an investment as *P. miniaceum* var. *involva*.

specimen of *Polytrema* often seen adherent to coral-rock, where the test has formed a meandering surface-growth rather than an arborescent structure.

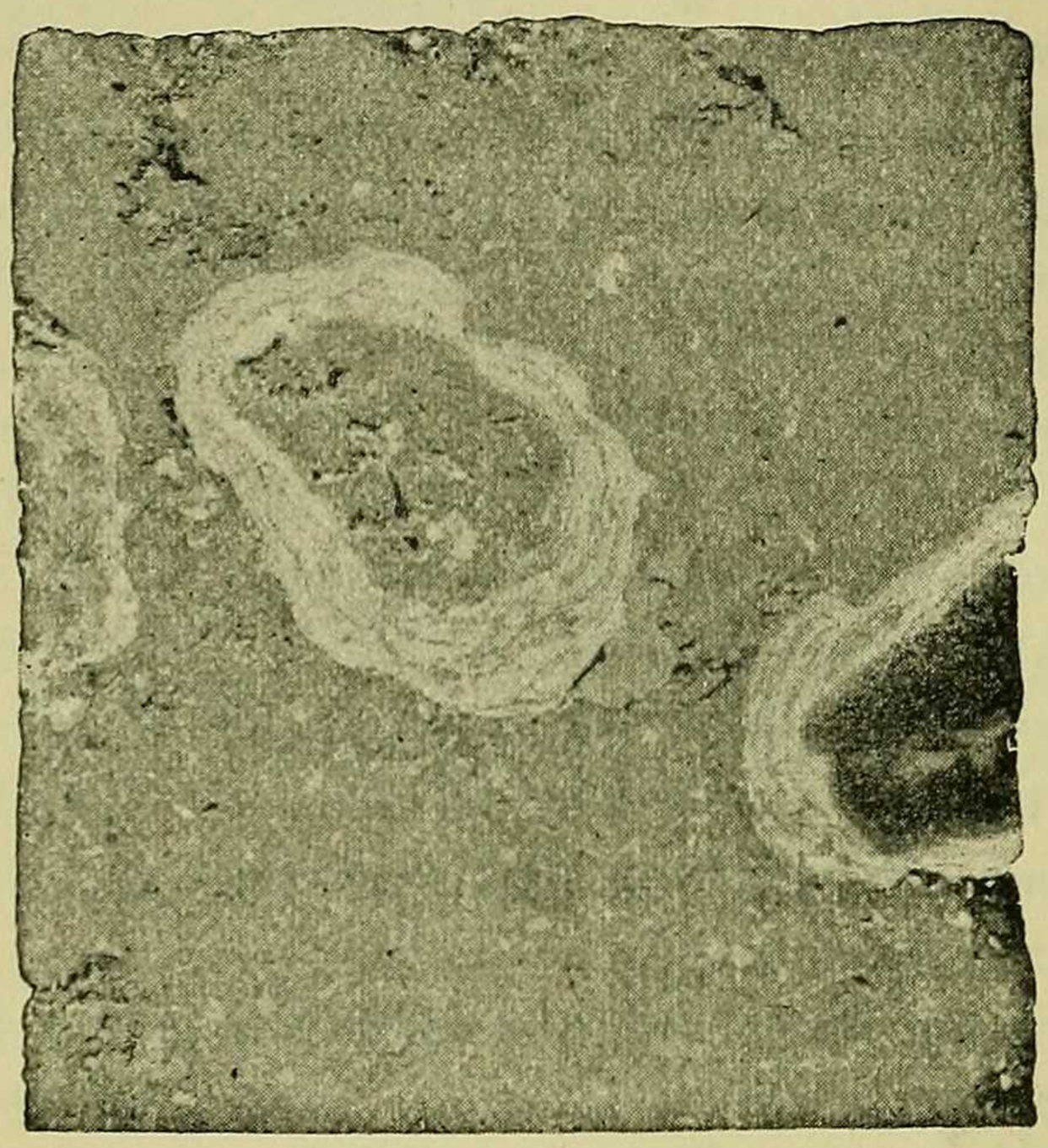

Fig. 2.—Core from boring, Funafuti Atoll, at 766 ft. Containing nodules of *Polytrema miniaceum* var. *involva* nov. Nat. size.

P. miniaceum var. *involva* occurs in the coarse beach-sand of the outer reef-slope at Funafuti, and also at various depths in the deep boring. Its occurrence in the latter is of very great interest. These nodules of intergrowth are scattered throughout the more sandy parts of the cores of limestone down to a depth of 640 feet, when they are more frequent and of larger development. The largest and most typical specimens come from about 660 feet, where they are embedded in an *Amphistegina*-sand. They are common in the cores down to about 790 feet, after that occurring occasionally, and usually forming smaller nodules.

P. miniaceum var. *involva* has also recently been noticed by the author in the Tertiary limestones of Christmas Island, associated with *Orbitoides*.

Family NUMMULINIDÆ.

Subfamily NUMMULITINÆ.

HETEROSTEGINA, *d'Orbigny* [1826].

HETEROSTEGINA DEPRESSA, *d'Orbigny*. (Pl. 3. figs. 6 & 7.)

Heterostegina depressa, d'Orbigny, 1826, Ann. Sci. Nat. vol. vii. p. 305, pl. xvii. figs. 5–7 ; Modèle, no. 99.

H. antillarum, d'Orbigny, 1859, Foram. Cuba, p. 211, pl. vii. figs. 24, 25.

H. simplex, d'Orbigny, 1846, Foram. foss. Vienne, p. 211, pl. xii. figs. 12–14.

H. helvetica, Kaufmann, 1867, Geol. Beschreib. des Pilatus, p. 153, pl. ix. figs. 6–10.

H. depressa, var. *simplex*, d'Orbigny, Goës, 1882, Retic. Rhizop. Caribb. Sea, K. Svenska Vet.-Akad. Handl. vol. xix. no. 4, p. 117, pl. viii. fig. 303.

H. depressa, d'Orbigny; Brady, 1884, Rep. 'Chall.' vol. ix. p. 746, pl. cxii. figs. 14–20; Egger, 1893, Abhandl. bayer. Akad. Wiss., math.-phys. Cl. ii. Bd. xviii. Abth. ii. p. 241, pl. xx. figs. 34, 35; Goës, 1896, Bull. Mus. Comp. Zool. Harvard, vol. xxix. no. 2, Memoir xx. p. 79.

As Dr. H. B. Brady has already pointed out in his monograph on the 'Challenger' Foraminifera *, *H. depressa* can be arranged in two series according to their form and external characters. After a careful study of the Funafuti specimens, I have been able to identify these two series with the dimorphic forms A and B respectively. The megalospheric form (A) embraces the involute, bi-convex type, with the asymmetric (spiral) flange; whilst the microspheric form (B) is represented by the compressed and explanate specimens. The difference between the primordial spheres of the two forms is not very great, but it is constant, their diameters being in the ratio of 3 : 2.

The megalospheric form is far more common than the microspheric, for in most samples it is in the proportion of about 500 to 1, or even greater.

The megalospheric form in *H. depressa* attains a larger diameter in full-grown specimens than the microspheric, which is unusual amongst the Foraminifera yet examined with regard to dimorphism, but nevertheless instances are known: for example, in *Adelosina polygonia*, Schlumberger, the megalospheric shell is slightly larger than the microspheric (1·5 to 1·4 mm.).

From so large a collection of specimens as we are now dealing with, possibly one of the most extensive from any particular locality, one may obtain a very complete idea of the extent of variation in a species from a given area. *H. depressa* in its megalospheric form varies greatly as to size and thickness, and the microspheric form varies curiously in its internal septal arrangement, to be noticed below. The two forms, however, are in themselves so distinct as to present little difficulty in relegating them to either series.

Form B has a thin and transparent, or translucent, shell-wall, and thus the septation can be clearly seen. The earlier portion shows no secondary septation dividing the chambers into chamber-

* Rep. Chall. vol. ix. p. 746, pl. cxii. figs 17, 18 19, 20.

lets; but after two whorls of the shell have been completed, and while the test is still small, rudimentary secondary septation begins at the peripheral angles of the chambers, after the manner of d'Orbigny's *Heterostegina simplex* *. The next stage in the septal division is seen after the completion of about four whorls, when straight, bar-like, but incomplete cross-septa are seen projecting from the septum proper, but which do not extend for more than $\frac{2}{3}$ across the chamber-cavity. In many specimens this incomplete septation is apparent to within the last few chambers, when it takes on the usual characteristic secondary septation of the Heterostegine type.

One specimen of the complanate type (B) from Funafuti exhibits a remarkable variation in having the secondary chamberlets themselves divided at right angles by a third series of septal bars.

The surface of the shell in this form (B) is usually granulate, or covered more or less with numerous hyaline papillæ, which are the rounded bases of cones of non-tubulous shell-substance, their points being directed inwards to the median plane. When the granules are arranged, as is sometimes the case, along the septal lines, we have the variation named by d'Orbigny *H. costata* †.

Form A, on the contrary, always possesses a smooth-surfaced shell.

Form B is found most frequently at a depth of 60 fathoms round Funafuti.

In the sarcode of a megalospheric form, which was stained with picrocarmine, a nucleus with a nucleolus was observed, measuring $70 \times 60\ \mu$.

A microspheric specimen contained, in the middle of the sarcode body, a group of about a dozen rounded particles, probably nutritive; whilst scattered through the body-substance there were seen six or more rounded algal cells (? symbiotic).

H. depressa is not confined to the outer side of Funafuti. It is equally common in the lagoon, where it often attains as large dimensions as specimens from the outside. Very large specimens have also been noticed in some of the deeper cores of the boring in the atoll. It is especially noteworthy that the largest specimens of *H. depressa* found at Funafuti, measuring nearly $\frac{1}{2}$ inch in diameter, were from dredgings at 32 and 36 fathoms outside Funafuti Atoll, N. of Pava (coll. by Prof. David).

* D'Orbigny's figures, however, appear to belong to form **A**.

† Foram. Foss. Vienne, 1846, p. 212, pl. xii. figs. 15–17.

Subfamily CYCLOCLYPEINÆ.

CYCLOCLYPEUS, *Carpenter* [1856].

This genus is very restricted in its distribution. It appears to find its most congenial habitat in tropical areas where the water is practically free from suspended terrigenous material.

From the investigations made round Funafuti we have learned of the remarkable and perhaps unique abundance of the various stages of this hitherto rare type. In point of fact only two other localities seem to have produced the larger form of *C. Carpenteri*, Brady, which often attains a diameter of $2\frac{1}{2}$ inches and merits the distinction of being the largest living foraminifer.

The study of the Funafuti specimens at first presented no slight difficulty on account of the occurrence of so many apparently distinct varieties in the material examined. This, however, was cleared away by the discovery of the interesting fact that the whole of the series illustrates different phases or stages of one species, which is dimorphic *.

In the course of obtaining additional knowledge regarding the coupling of species hitherto considered distinct, it seems most desirable to adhere to the principle of priority in the nomenclature of such dual forms, retaining the earlier of the two names for the pair. For example, in the following pages under the description of the Funafuti specimens of *Cycloclypeus*, two already described species are included in one specific type as the two stages of that species; namely, *C. Guembelianus* and *C. Carpenteri*, the former representing the young of form A, the latter appearing to include forms A and B. The latter species was not named by Carpenter, who figured, however, a large megalospheric specimen (A), whilst he described the exceptionally large examples from Borneo which are now seen to be the adults of form B. With regard to the name which the recent *Cycloclypeus* should now bear, the rule of priority in any case must be considered; but in this it curiously happens that both species date from 1881, and since Carpenter figured both forms A and B, we may therefore keep the name by which Brady designated Carpenter's original specimens, namely *C. Carpenteri*.

The recent *Cycloclypei* are limited to the station off Borneo, where they were dredged from a considerable depth by Capt. Sir

* In the sense employed by Munier-Chalmas and Schlumberger.

Edward Belcher; also from Kandavu, Fiji, 210 fathoms, form B (in the British Museum, Natural History, labelled *C. Carpenteri* in Dr. H. B. Brady's handwriting); from Mauritius (specimens of form A found by the Author, through the kind offices of Prof. Jeffrey Bell, on a *Turbinaria* in the British Museum); and from the Solomon Islands, amongst specimens which Capt. Guppy had sent Sir John Murray * (a specimen of form A). There is also an irregular, annulate variety in the British Museum, probably of *C. Carpenteri* (form A), from the Macclesfield Bank, China Sea, 30 fathoms.

The genus *Cycloclypeus* is also represented as fossils in the Tertiary limestones of early date on the S.E. coast of Arabia (*Carter*); from the Tertiaries of Java (*Martin*); and from similar rocks in Borneo (*Newton & Holland*).

CYCLOCLYPEUS CARPENTERI, *Brady*. (Pl. 2. figs. 6, 7; Pl. 3. figs. 1–5.)

Form A.

Cycloclypeus, Carpenter, 1856, Phil. Trans. vol. cxlvi. p. 155, pl. xxx. figs. 1 & 3; idem, 1862, Introd. Study Foram. p. 292, pl. xix. fig. 2.

C. Guembelianus, Brady, 1881, Quart. Journ. Micr. Sci., n. s., vol. xxi. p. 66 (young form); idem, 1884, Rep. Chall. vol. ix. p. 751, pl. cxi. figs. 8 *a*, *b* (young form).

C. Carpenteri, Brady, Lister, 1895, Phil. Trans. vol. 186 B. pp. 437, 438, pl. ix. figs. 52–54.

C. Guembelianus, Brady, Verbeek and Fennema, Descr. géol. Java et Madoura, vol. i. pl. ix. fig. 127.

Form B.

Cycloclypeus, Carpenter, 1852, Phil. Trans. vol. cxlvi. p. 555; idem, 1862, Introd. Study Foram. p. 292.

C. Carpenteri, Brady, 1881, Quart. Journ. Micr. Sci., n. s., vol. xxi. p. 67; idem, 1884, Rep. Chall. vol. ix. p. 751; Martin, 1896, Jaarb. Mijn. Ned. Oost-Ind. pp. 53, 54.

The series of specimens, which, from a biological standpoint, is referable to one species, consists of two dimorphic types, each represented by immature and adult specimens, with here and there some gradational links. It is a significant fact, which asserted itself during the examination of the specimens from Funafuti, and is borne out by material from other localities, that the young and the adult stages of the shell in each form, A and

* To whom the author is indebted for the opportunity of examining these and other specimens at the 'Challenger' Office.

B, are much more numerous than the specimens which link them together in the intermediate stages of growth; and this seems to be further corroborated by the internal shell-structure, which shows an apparent resting-stage in the shell-development, bounded by an irregular periphery, which differs from the broken and subsequently repaired rings of chamberlets.

Description *:—

Form A (megalospheric form).—Test discoidal, outline circular, or nearly so; the central area umbonate or biconvex, in full-grown specimens occupying about one-third the entire diameter of the shell. The initial series of chamberlets are enclosed in a secondary growth of shell-substance which gives rise to the umbonate shape of the central area of the disc. Beyond the central thickened area the annuli of the chamberlets are thin and compressed, forming a broad flange around the centre. For the first two or three annuli the chamberlets are approximately square, or even laterally elongated, but they subsequently become more radially elongated, not to so great an extent, however, as in the microspheric form next described.

Diameter of test $\frac{1}{16}$ inch to $\frac{7}{16}$ inch.

The megalosphere of a typical specimen of form A from Funafuti measured $260 \times 240\,\mu$. It is ovate, with one end pointed and the other rounded, and it lies in the concave sides of two crescent-shaped chambers, following upon which are the annuli of small chamberlets †.

The nucleus observed by Lister was seen in one case to occupy the megalosphere, and in another it was found in the second chamber; that in the megalosphere was of an oval shape, measuring $60 \times 40\,\mu$, whilst the nucleus seen in the second chamber was nearly spherical, measuring about $85\,\mu$ in diameter. In the specimens from Funafuti which I decalcified and stained with picro-carmine no nucleus was observed in the central area of the disc, but irregular and ovoid nuclear bodies were seen in the last series of annuli, in many cases extending through an adjacent chamber. The structure of the nucleus was somewhat granulate with darker enclosures, like those observed by Lister.

* Dr. Brady's description of the young of form A (= *C. Guembelianus*, Brady) now applies to the central area of the disc of full-grown specimens of the megalospheric type. See p. 751, Rep. Chall., vol. ix. 1884.

† See also Lister, *op. cit.* p. 438.

Form B (microspheric form).—Test discoidal, outline circular; in young individuals very thin, and with the surface granulate. The central area in young and middle-sized specimens is occupied by a small boss, about one-half the diameter of that in the megalospheric form; after the test has attained the diameter of about 15 mm., this central prominence is soon levelled over, since at that period the animal thickens its superficial shell-layer, and covers over any irregularity of surface, including the papillate ends of the non-tubulous cones of the shell-wall.

Diameter of test $\frac{1}{32}$ to $2\frac{1}{2}$ inches.

In *C. Carpenteri*, especially in the microspheric form (B), the concentric rings of chamberlets are frequently incomplete owing to the fracture of the periphery during the growth of the animal, which repairs the edge at first by a series of chamberlets parallel with the broken edge, the length of each chamberlet being in succeeding annuli of increasing proportion in the parts requiring more material to bring the contour of the disc back again to its circular form. In this ability to repair the fracture, to which it is so liable on account of its form and thinness, it resembles *Orbitolites* in the porcellanous group, and especially *O. tenuissima*, Carpenter, who has already pointed out * that this phenomenon is commoner in the genus *Cycloclypeus* than in *Orbitolites*.

The microsphere of a typical specimen of form B from Funafuti measured 140 μ in diameter.

It is difficult to obtain specimens of the full-grown microspheric form which show the central chamber intact, for in nearly all cases the median area, containing the sarcode, has been cleared away by a species of *Cliona*.

Distribution around Funafuti, and in other localities in the Pacific.—The general geological and geographical distribution of *Cycloclypeus* has been already given (see *anteà*, pp. 21, 22).

Cycloclypeus Carpenteri has never yet occurred in the lagoon dredgings, although nearly all the other genera of Foraminifera found at Funafuti have been found irrespectively inside the lagoon and on the outer side of the reef.

The depths at which *Cycloclypeus* has been found in the dredgings made by Messrs. Halligan and Finckh are as follows:—

The young of both forms (A and B) from 30–200 fathoms.

The fully-developed form of A from 30–200 fathoms.

The fully-grown microspheric form of B from 46–200 fathoms.

* Phil. Trans. vol. cxlvi. (1856) p. 556.

At a depth of from 50–60 fathoms large quantities of both A and B were dredged in equal proportion.

The immature stage of form A is common in some dredgings around Funafuti, where the form B is sometimes entirely absent. This small form, the original of Dr. Brady's *C. Guembelianus*, is seen to graduate into the larger forms of the same type, which when fully-grown attain a diameter of $\frac{7}{16}$ inch (11 mm.). These fully-grown specimens had not been observed by Brady in the 'Challenger' collection, for he remarked *:—"Notwithstanding their minute dimensions in comparison with the only other recent species hitherto obtained, they are to all appearances fully grown."

Brady, however, appears to have seen the adult specimens later, since there are some examples in the Brady collection at the British Museum (Natural History) of this type, probably obtained by him on his visit to Fiji.

The larger of those specimens examined by Lister appears to be a fully-grown individual of the form A; these were obtained from the S.E. of Nomuka in the Tonga Islands, at a depth of 20–40 fathoms. The young of form A (=*C. Guembelianus*) was recorded in vol. ix. of the 'Challenger' Reports † from Station 174 C, off Kandavu, Fiji Islands, at 210 fathoms. In the 'Summary of Results,' however, the record reads "Station 172 A, off Tongatabu, at 240 fathoms" ‡.

The various records for *Cycloclypeus Carpenteri* around Funafuti are as follows, the localities being taken in rotation N. E. S. & W.:—

North of Pava Id.—At depths varying from 36 to 63 fms. At 36 fathoms examples of *Cycloclypeus* consisted chiefly of the immature forms of the megalospheric type. A specimen (adult form A) from 63 fathoms is partially enclosed in an encrustation of *Lithothamnion*—an illustration of the consolidation of reefs by the intergrowth and overgrowth of organisms.

Off Funamanu Id. (*Beacon Id.*).—Form A occurs at 50 fathoms, very common, especially the young form; at 80 fathoms there were very large examples of form B, encrusted with Polyzoa, and with *Carpenteria* and other adherent Foraminifera; and at 150 fathoms good typical examples, fully developed, of form A.

* Rep. 'Challenger,' vol. ix. p. 751.

† Pp. 92, 93, & 752.

‡ Summary of Results, 1st part, p. 631.

S.W. end of Funafuti.—At 45–51 fathoms, "a bottom of hard rock" (label on specimen). The tests are here stained a dark rich green in the central area, due to the presence of algæ in the chamberlets.

Off Tutanga Id.—Form A occurred at 35, 41, and 46 fathoms (at 41 fathoms numerous specimens of both forms were found resting on pink *Lithothamnion* in their places of actual growth); at 50–60 fathoms in association with form B; and at 200 fathoms. Form B was obtained at 46 fathoms; at 50–60 fathoms in association with form A, both very abundant; at 135 fathoms, common; and at 200 fathoms in a pteropod ooze, in association with the form A and at all stages of growth.

Off Fuafatu.—Form A, 30–120 fathoms, common; at 40 fathoms the specimens are stained, especially towards the central area, with a dark green (? symbiotic) alga; at 60 fathoms, common. Form B, at 60 fathoms, common; at 119 fathoms, a fragment.

The work of describing these specimens has been mainly carried out in the Geol. Division of the Royal College of Science, to which Institution the collections have been sent. All recent specimens described in this paper will be eventually placed in the British Museum (Natural History).

EXPLANATION OF THE PLATES.

Plate 1.

Fig. 1. *Sagenella frondescens*, Brady. A fragment of the branching test, detached, and viewed by transmitted light. The wall of the test over the sarcode-cavity is perforated by thread-like boring algæ. × 50.

2. *S. frondescens*, Brady. A fragment of the central area of the wall more highly magnified, exhibiting a reticulose character, and with a boring alga at *f*. × 300.

3. *Bdelloidina aggregata*, Carter. × 4.

4. *Valvulina Davidiana*, sp. nov. × 25.

5. *Peneroplis* (*Monalysidium*) *polita*, subgen. et sp. nov. × 50.

6. „ „ *Sollasi*, „ „ × 50.

7 *a–c*. *Spirillina spinigera*, sp. nov. × 50.

8 *a–c*. „ *tuberculato-limbata*, sp. nov. × 50.

9 *a–c*. *Discorbina tuberocapitata*, sp. nov. × 50.

10. *Calcarina hispida*, Brady, var. *pulchella*, nov. × 18.

Plate 2.

Fig. 1. *Sagenella frondescens*, Brady, attached to test of *Cycloclypeus Carpenteri* Brady. × 5.

2. A prolific growth of *Sagenella frondescens* attached to a large specimen of the microspheric form of *C. Carpenteri*. × 2.

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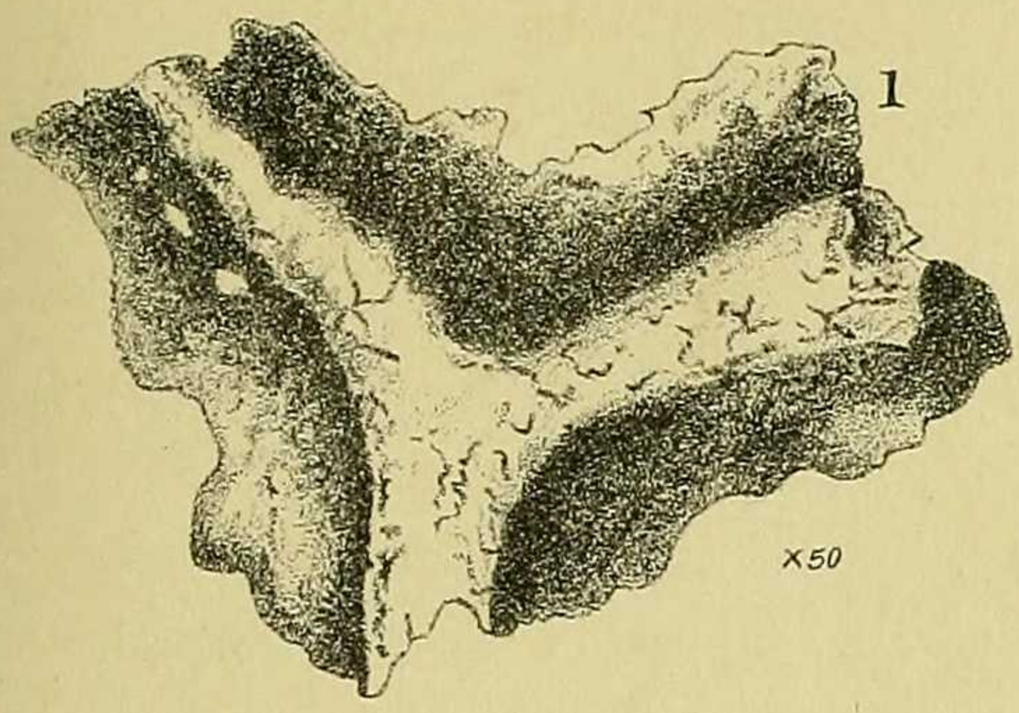

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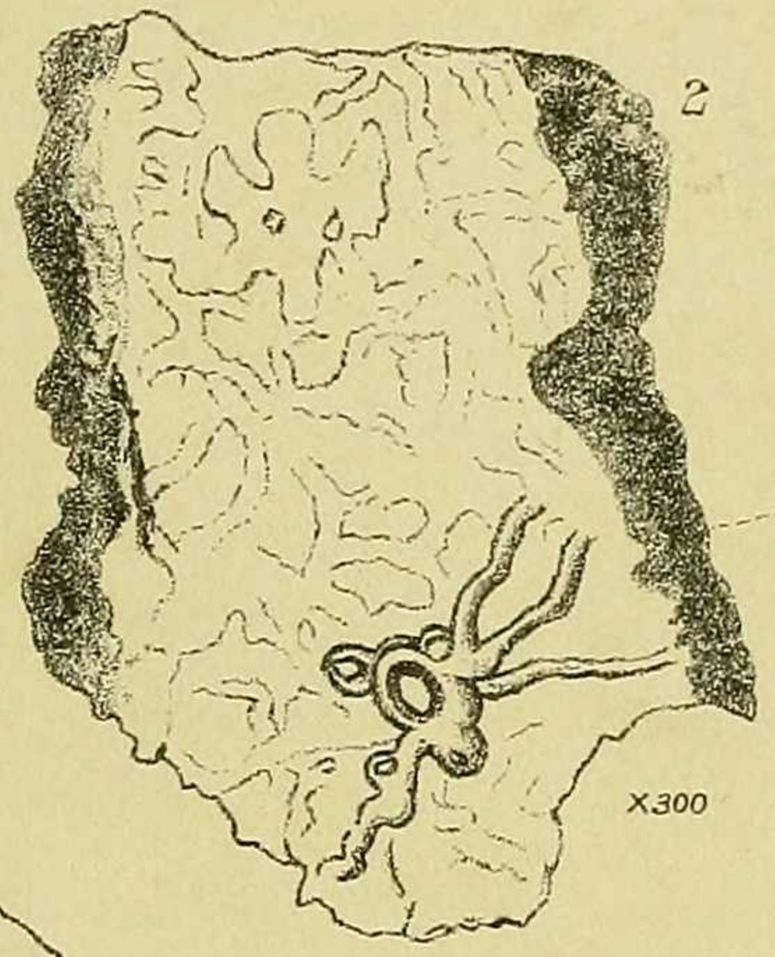

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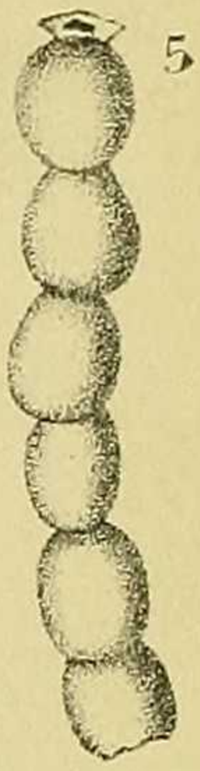

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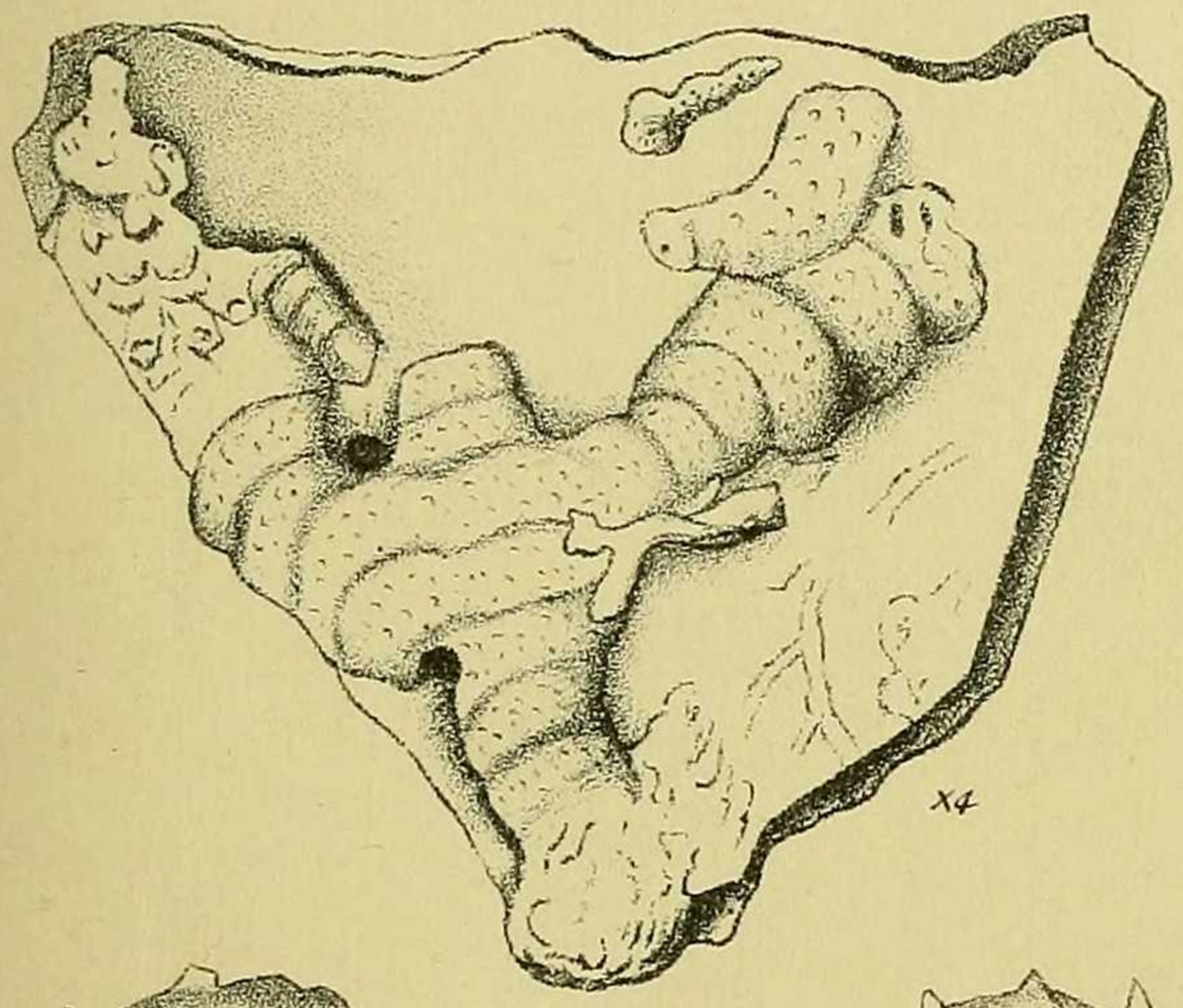

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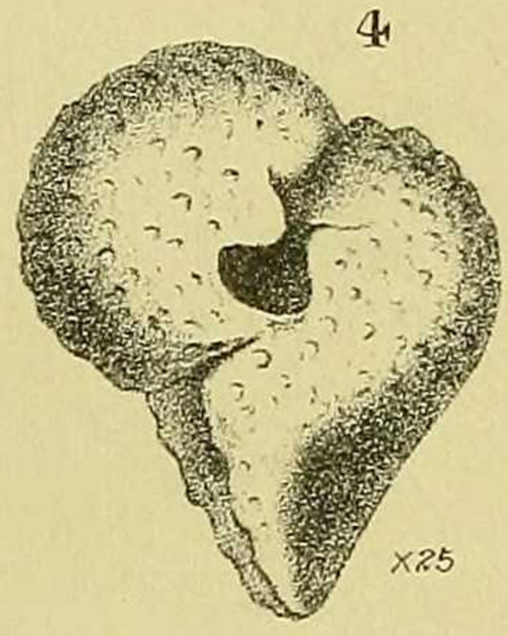

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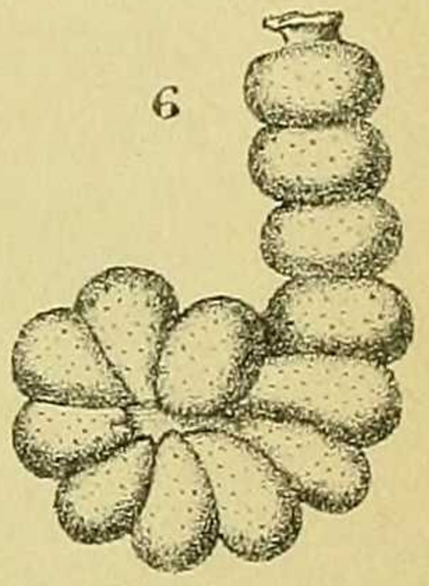

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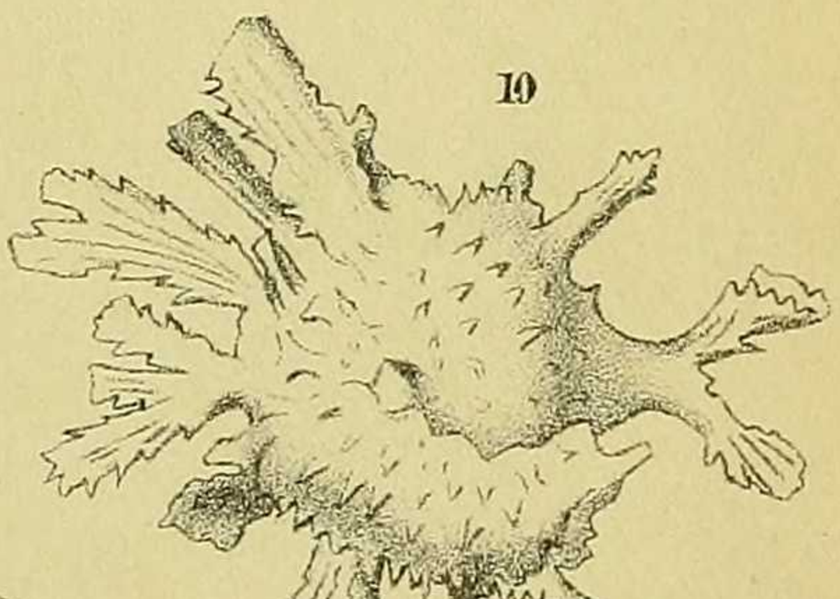

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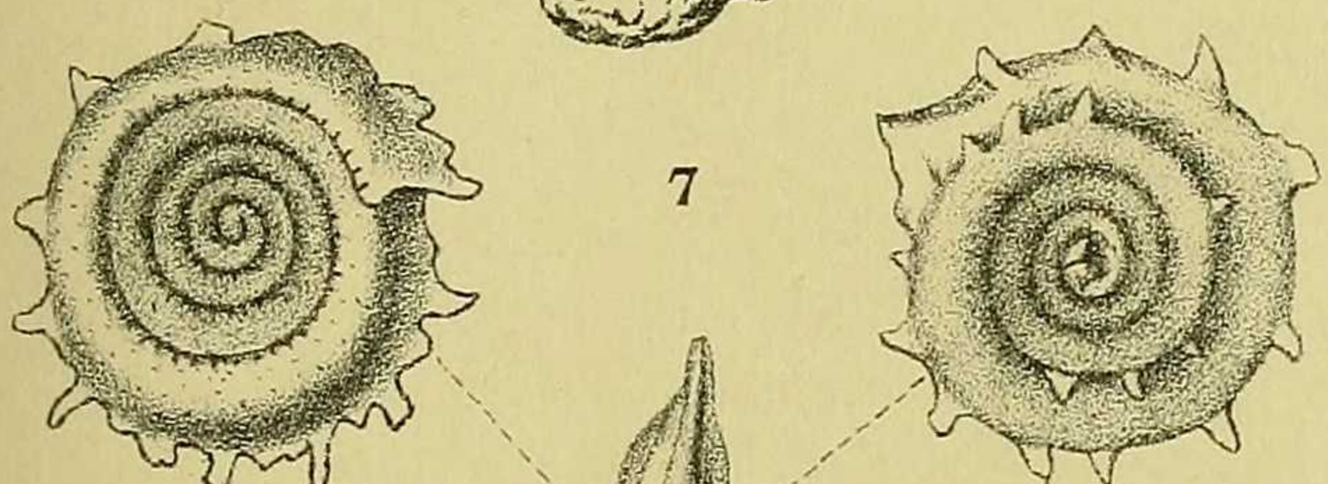

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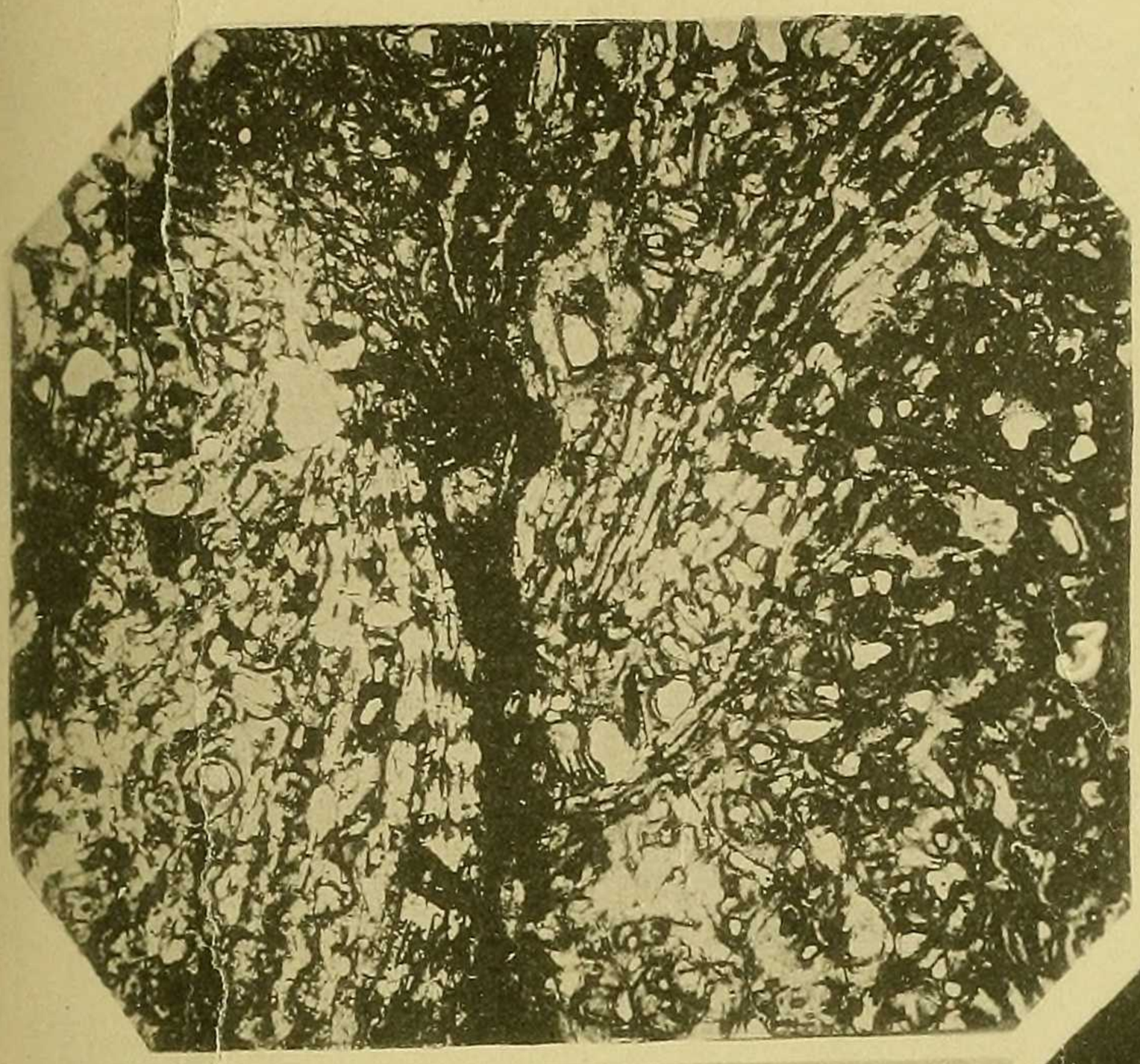
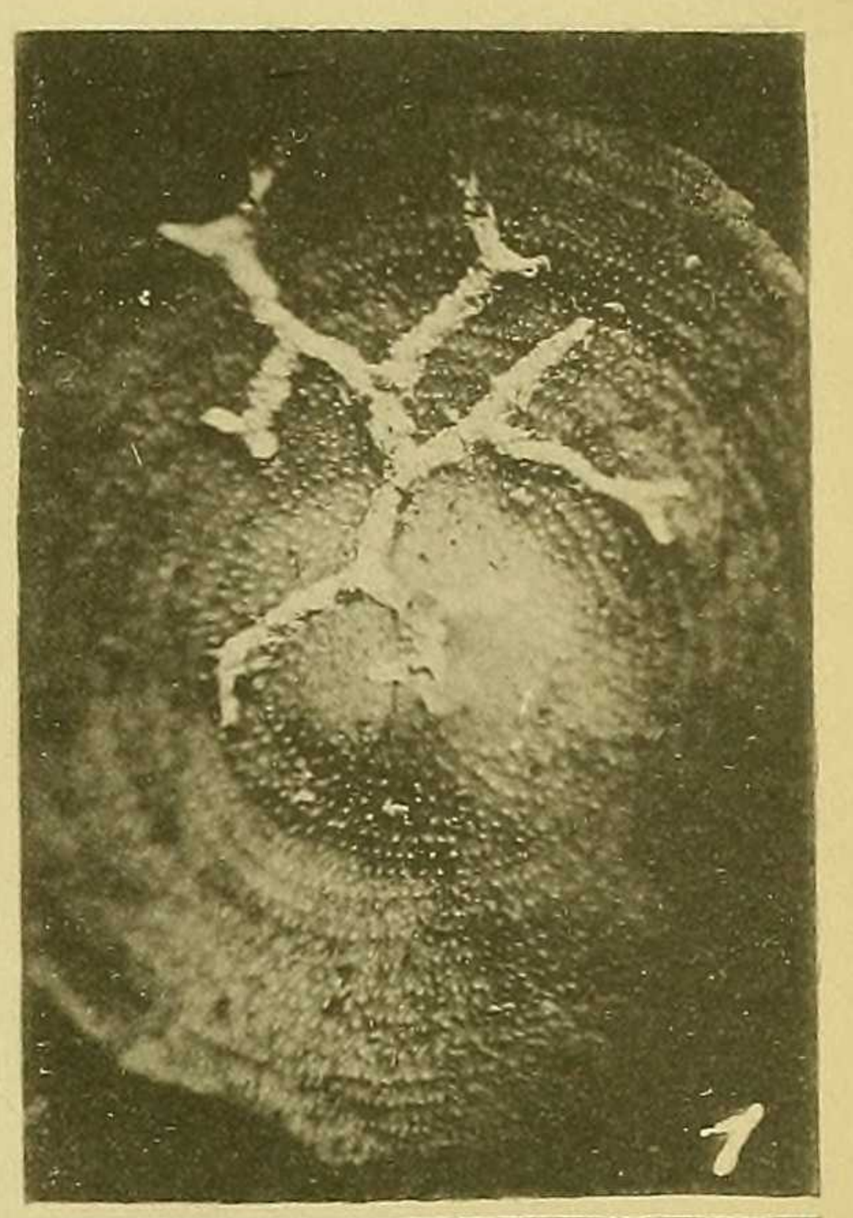
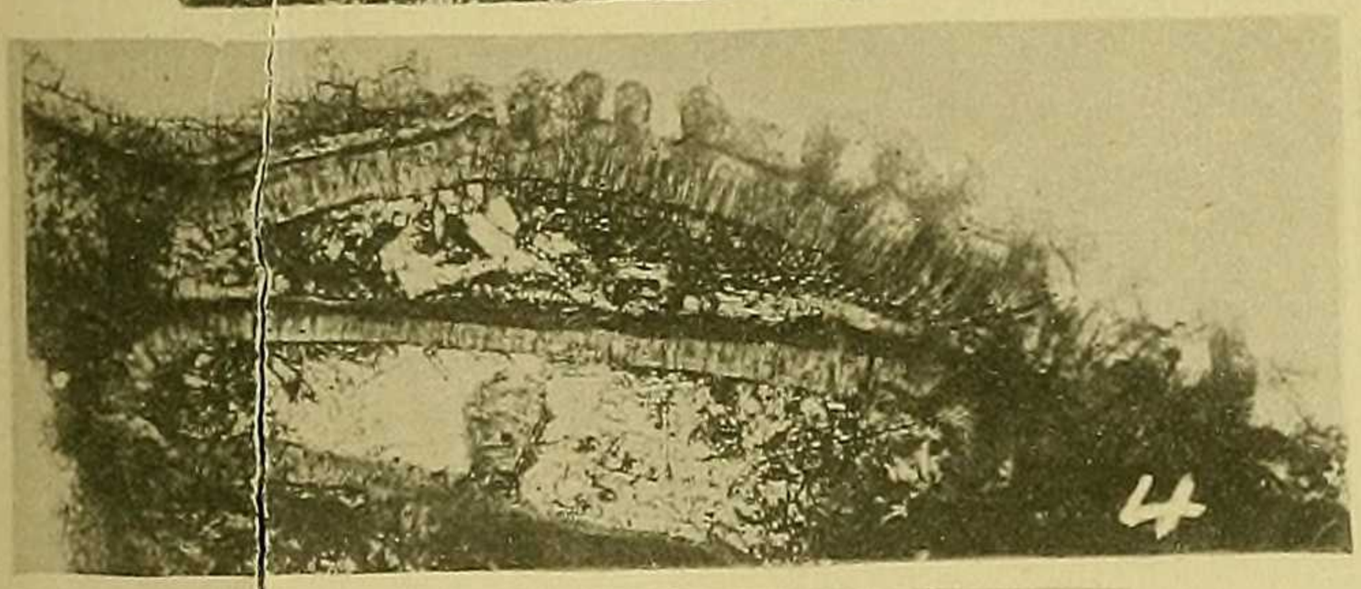
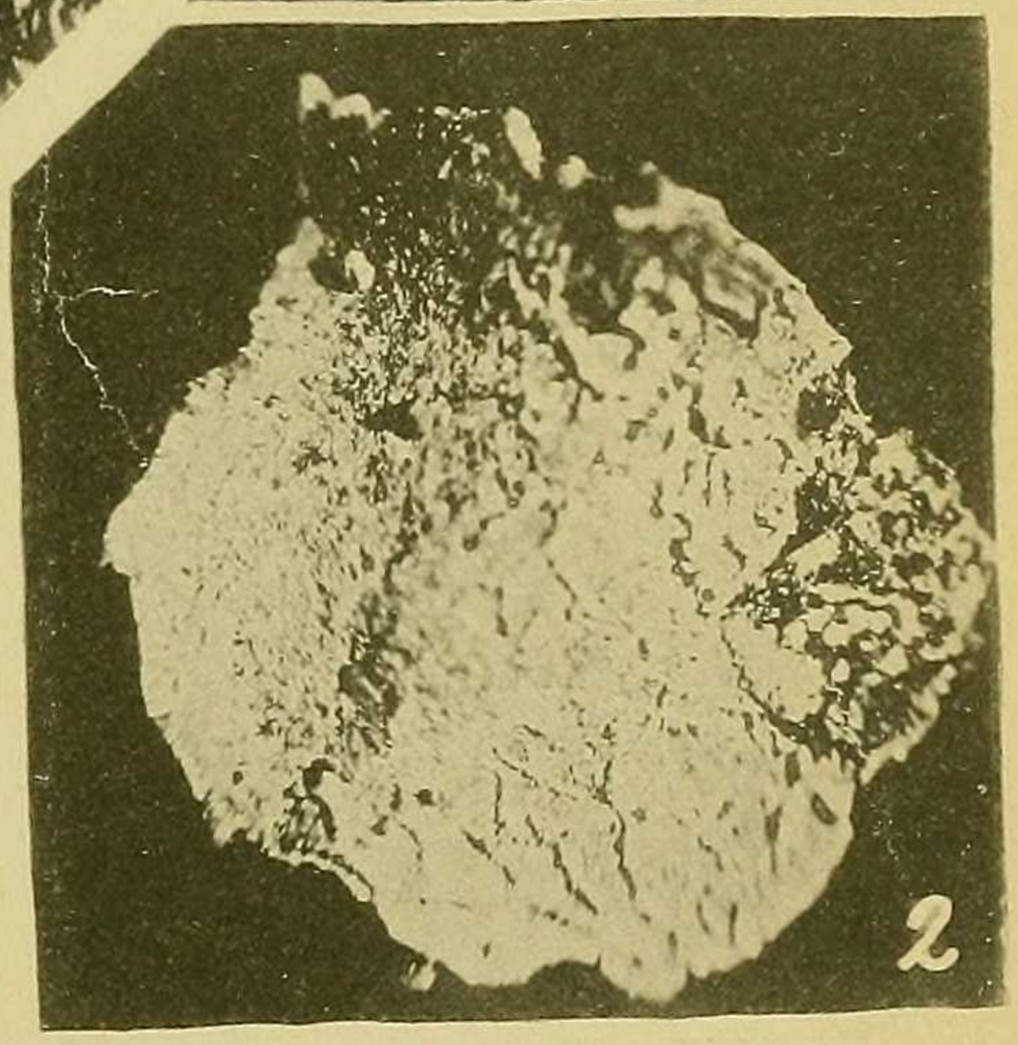
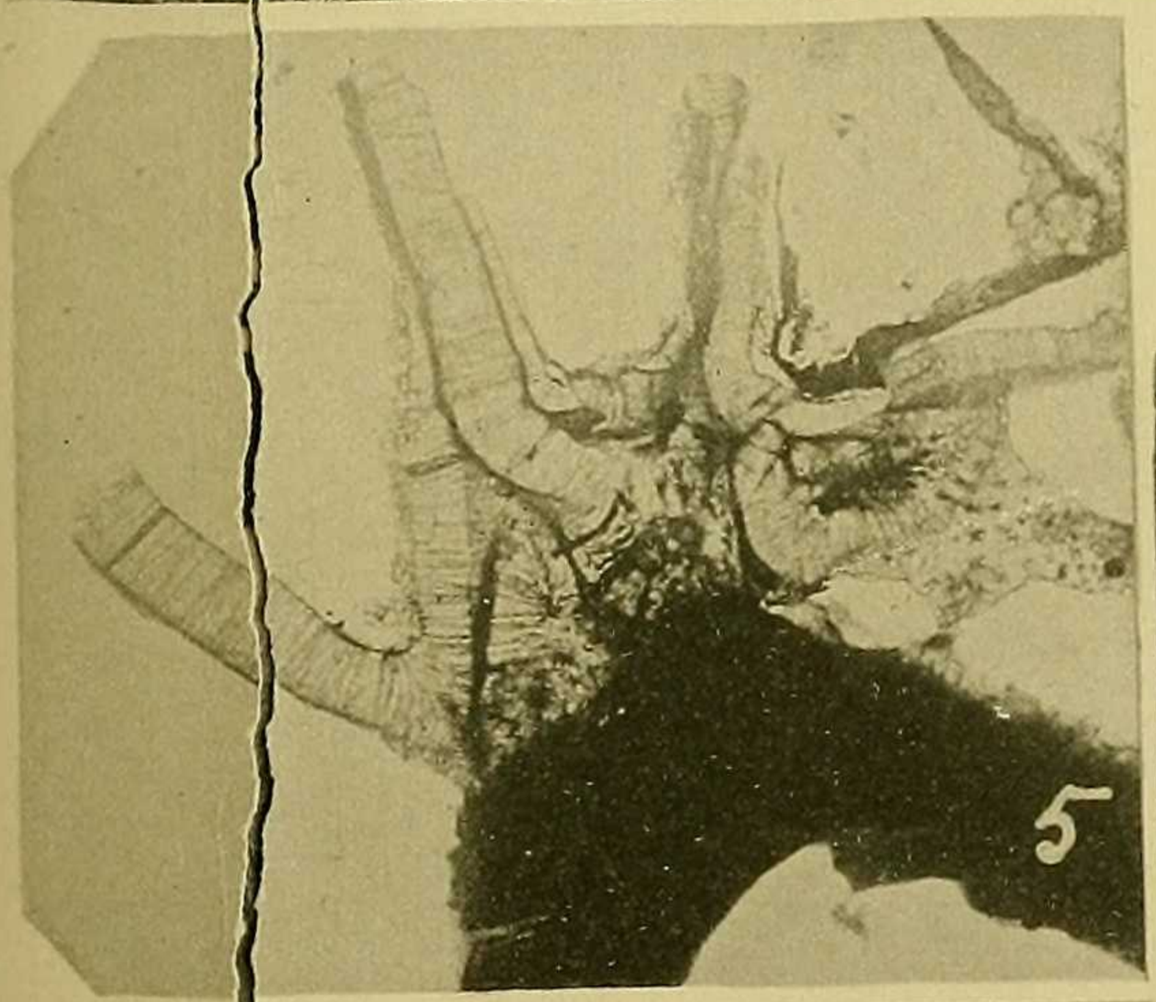
FORAMINIFERA FROM FUNAFUTI.

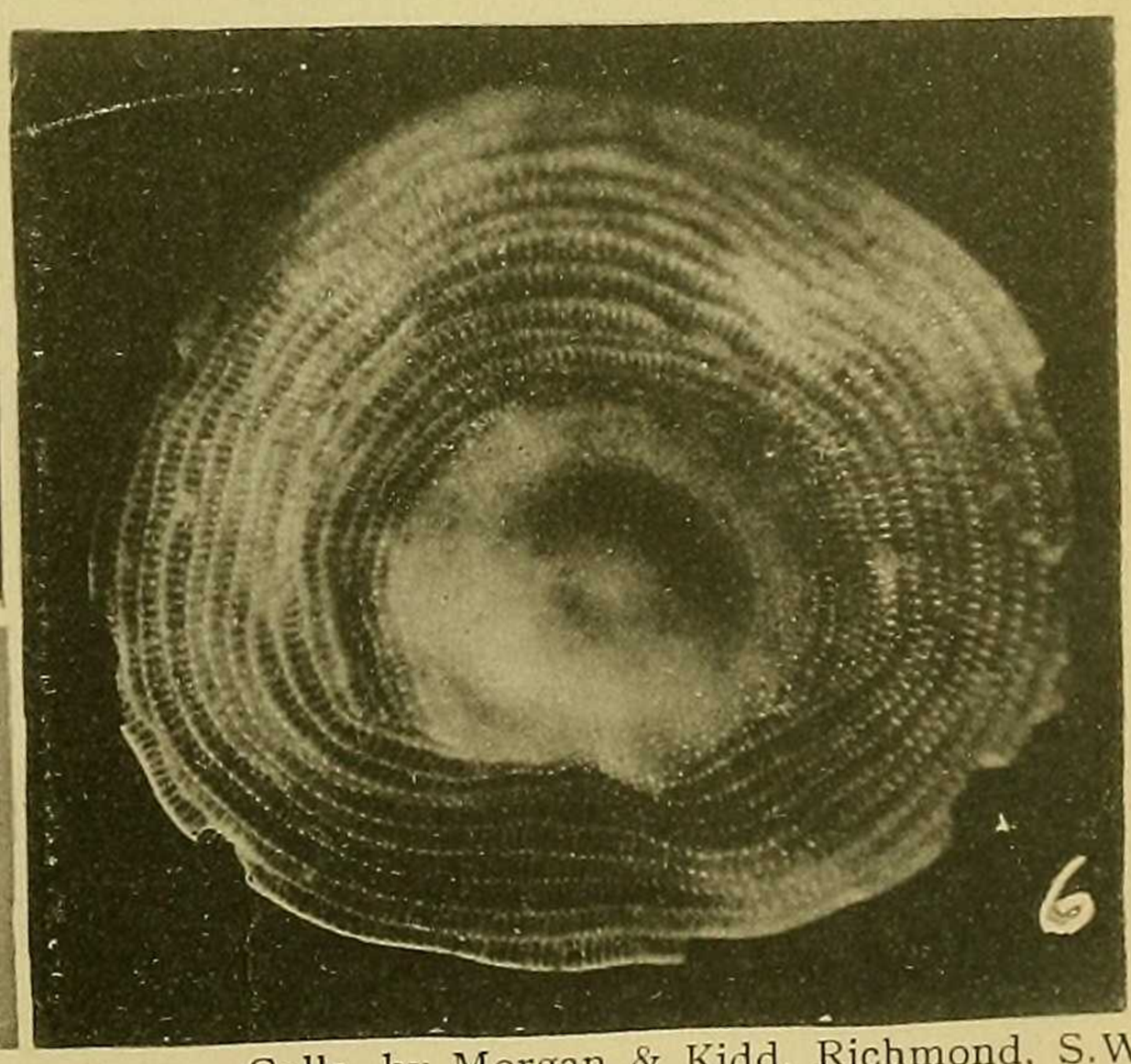


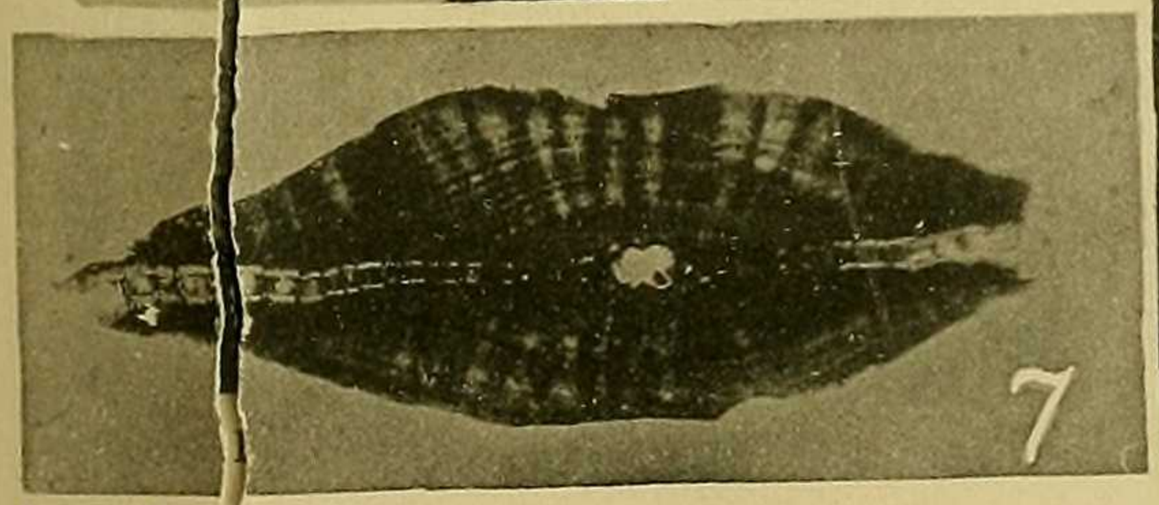












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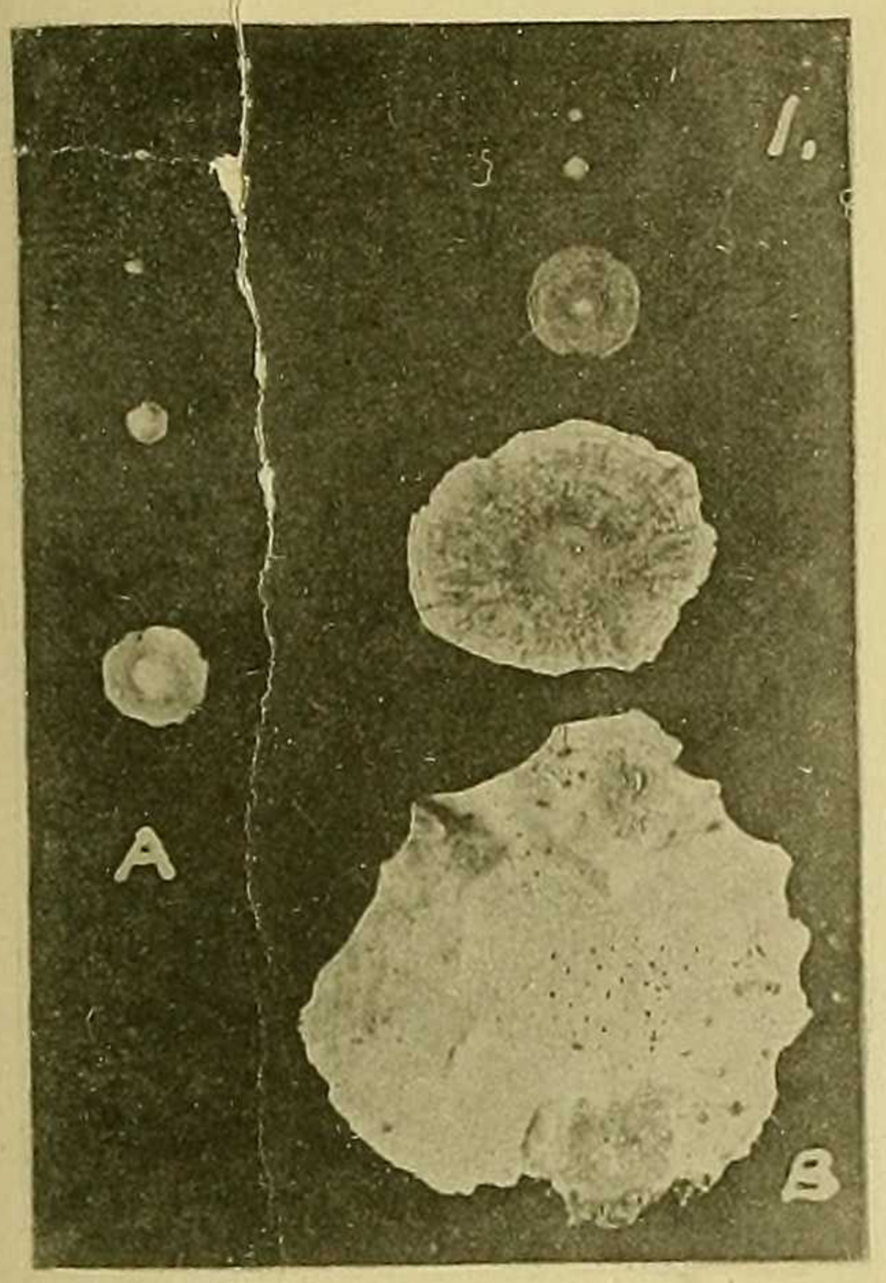
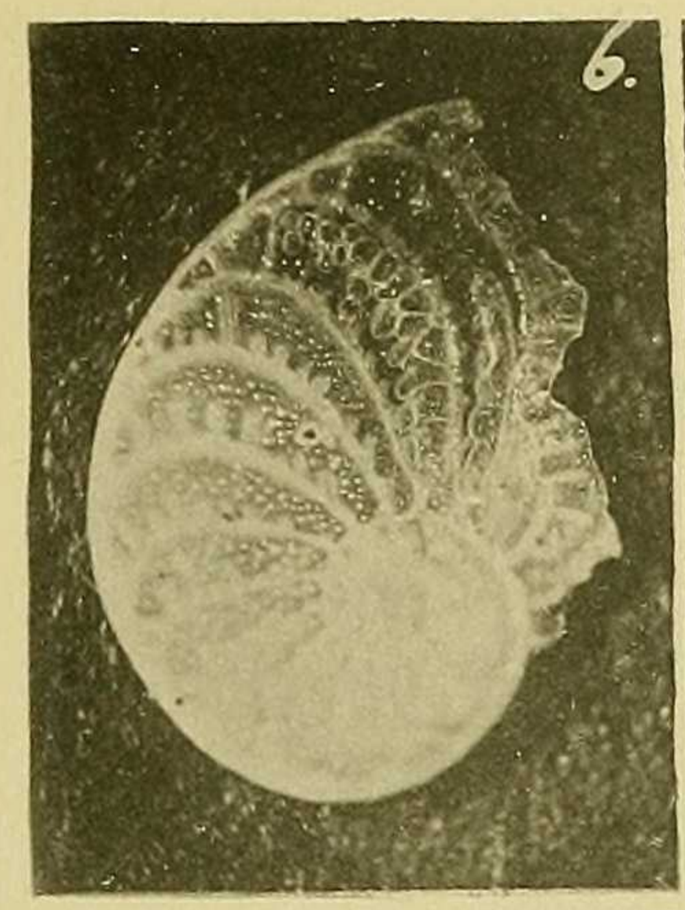
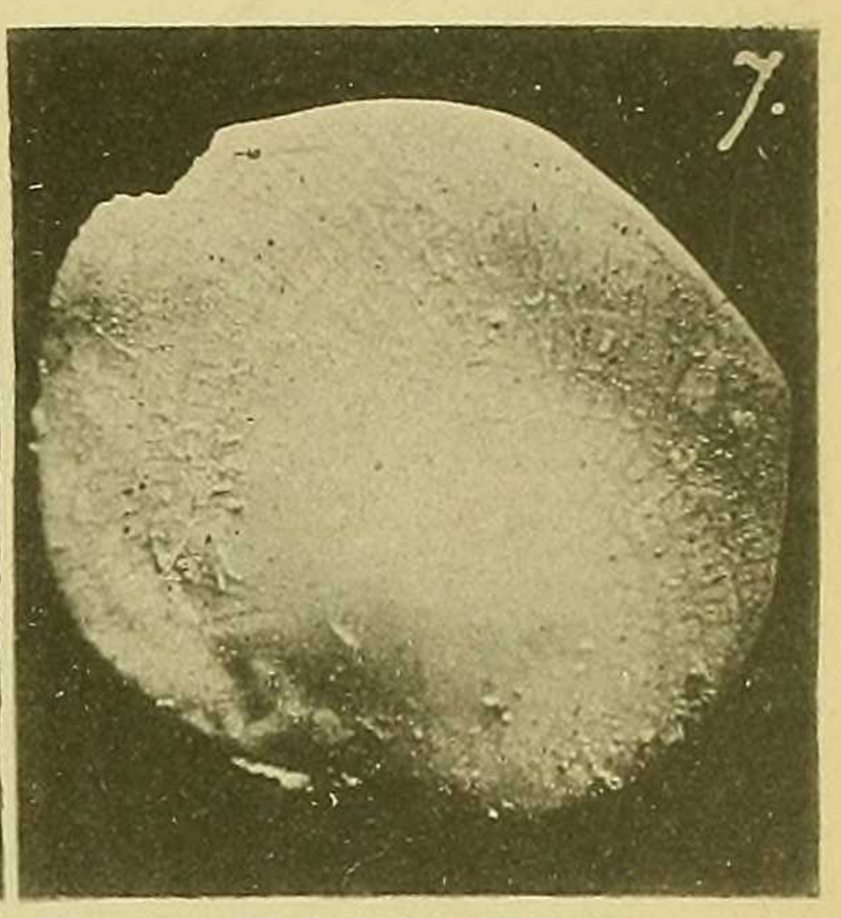
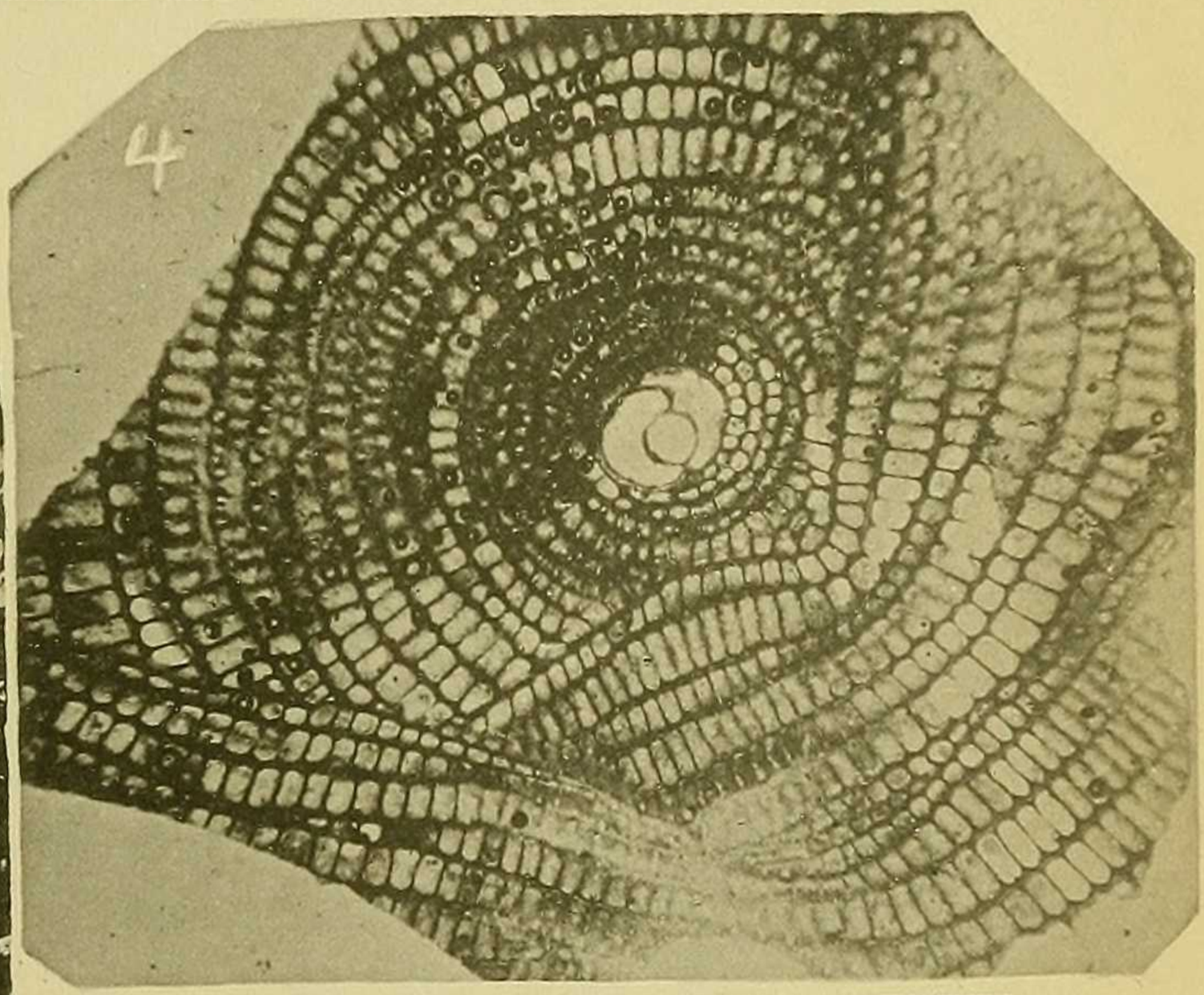
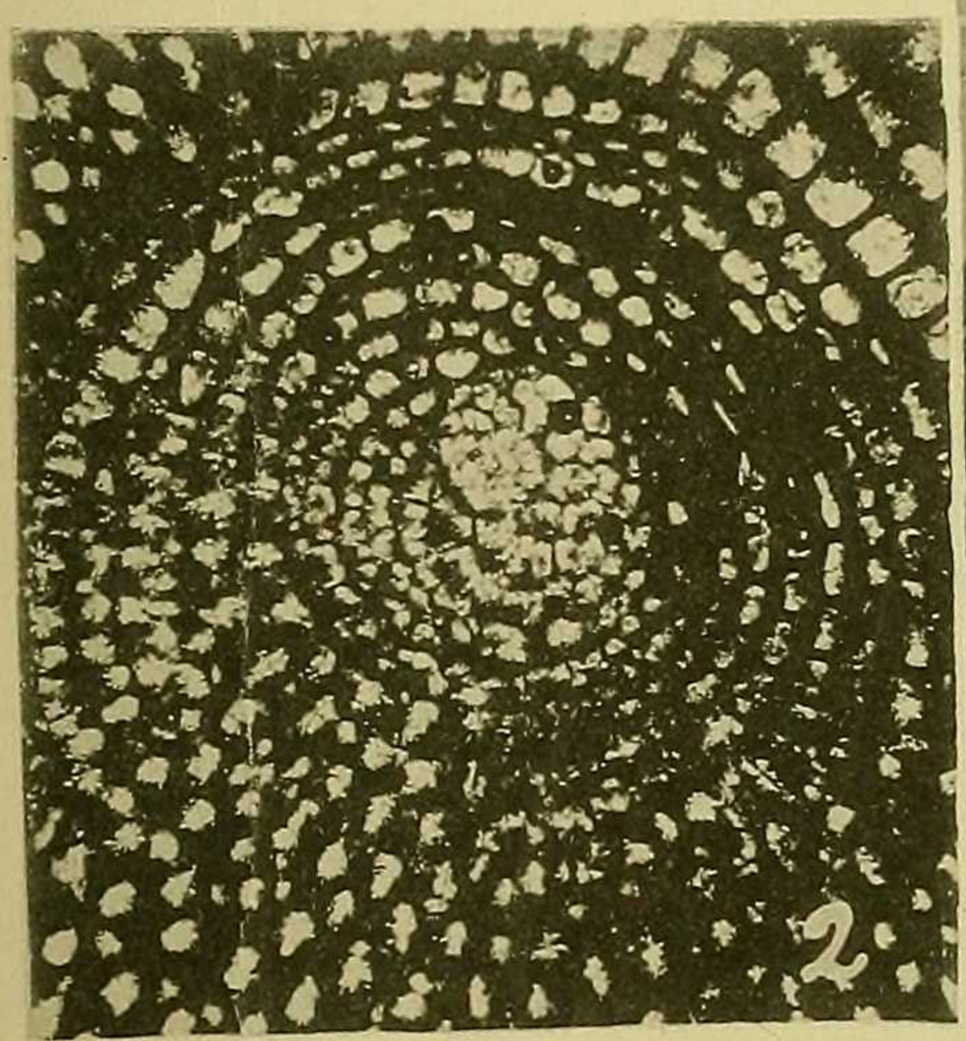
SAGENINA, CARPENTERIA, POLYTREMA AND CYCLOCLYPEUS FROM FUNAFUTI.

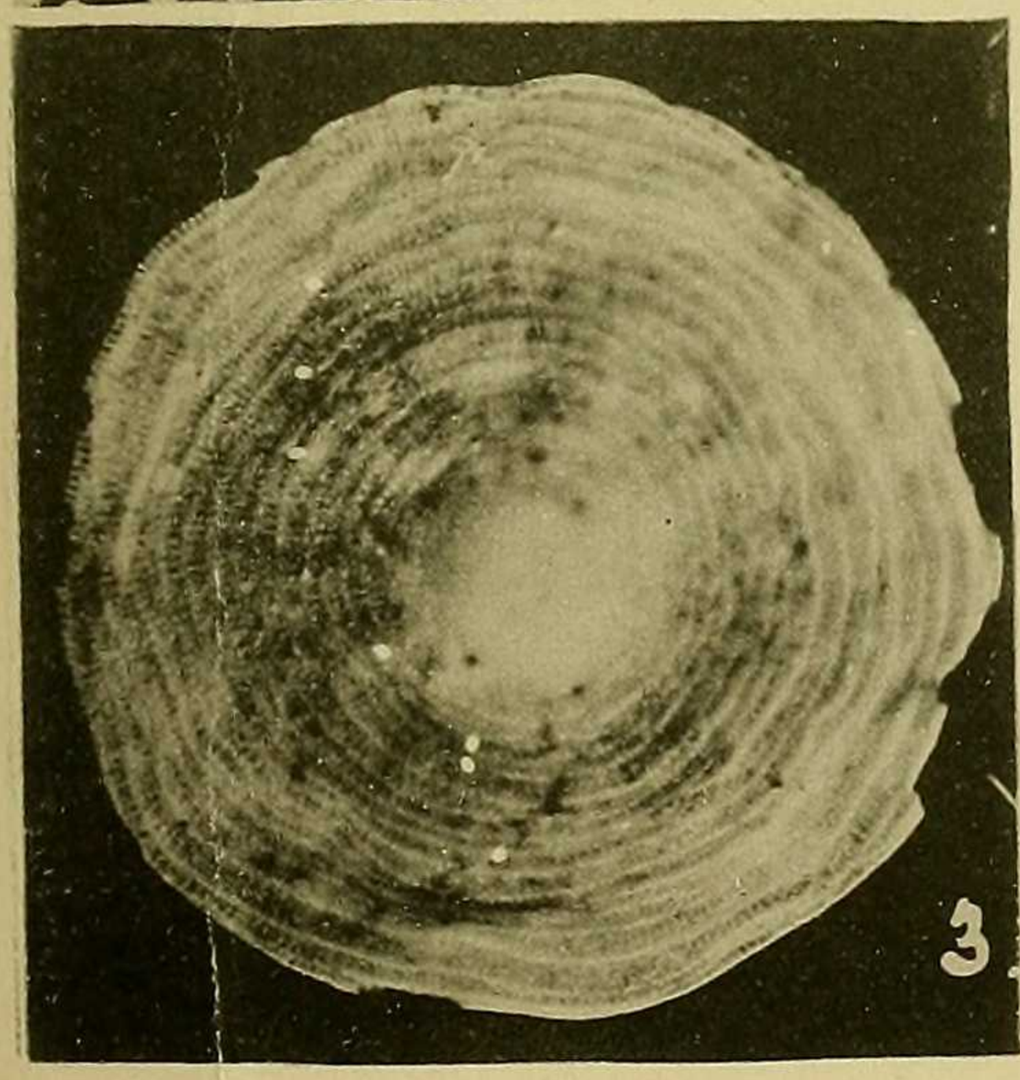


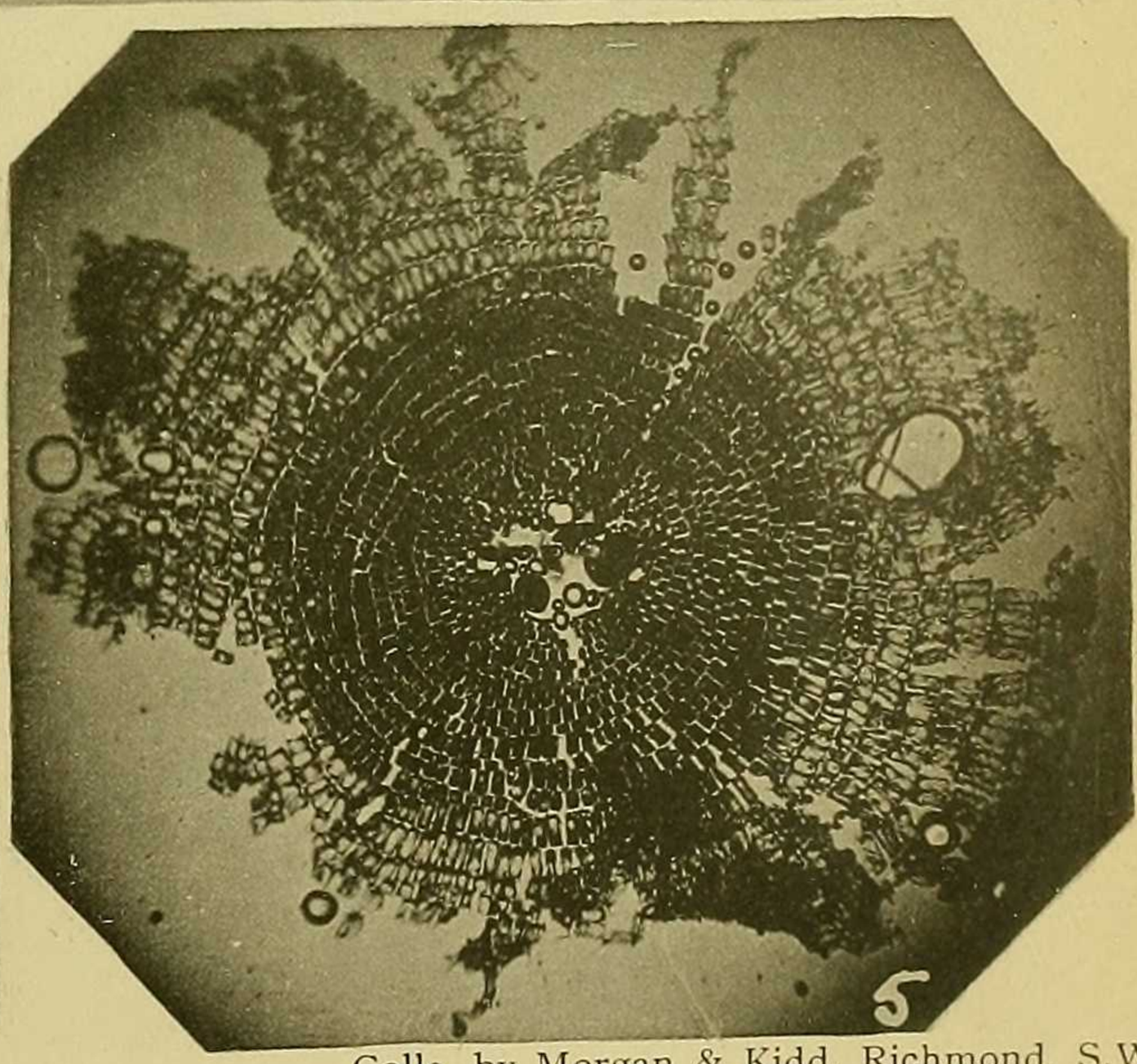












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HETEROSTEGINA AND CYCLOCLYPEUS FROM FUNAFUTI.

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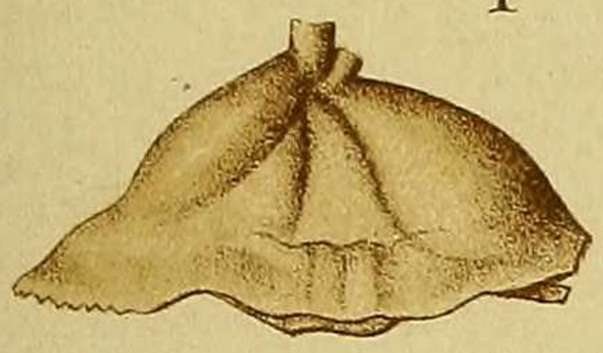

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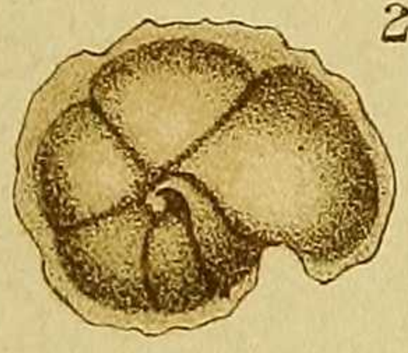

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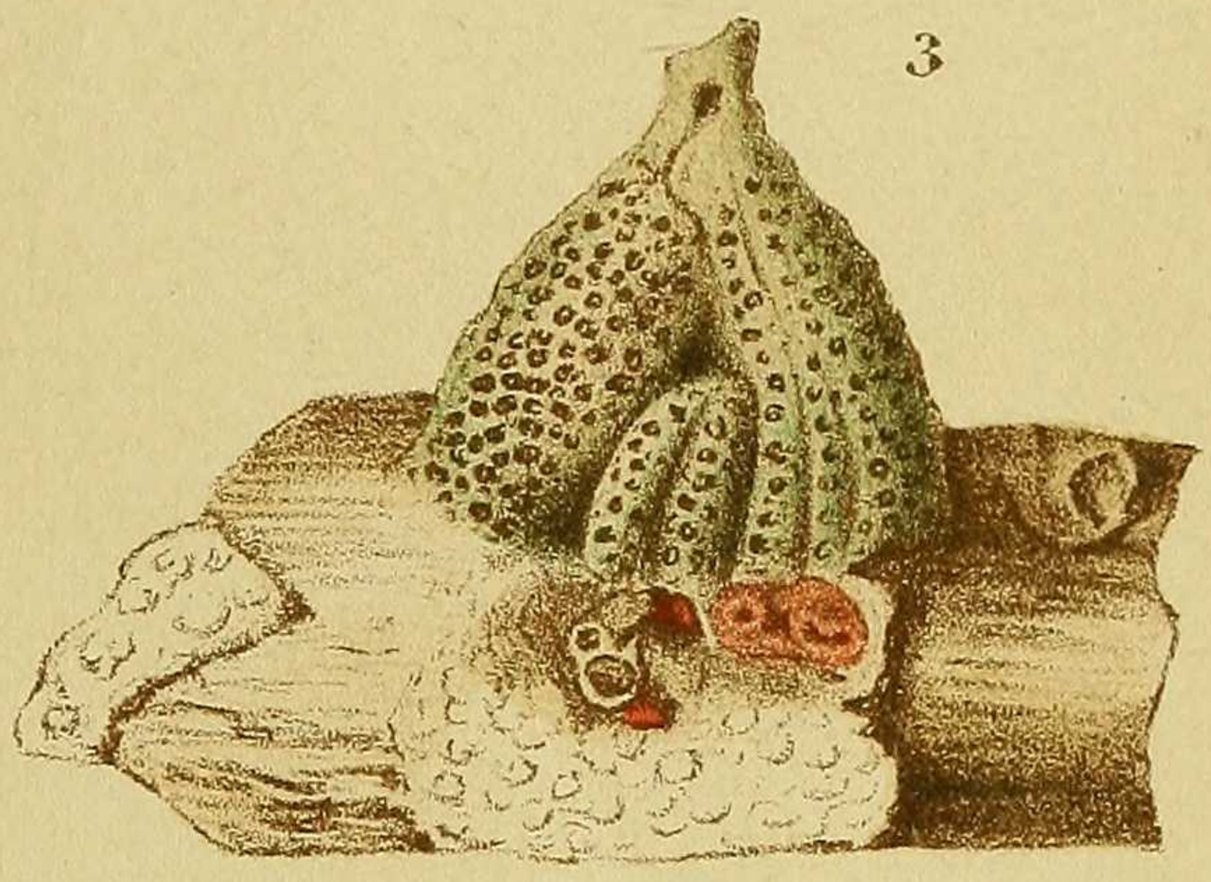

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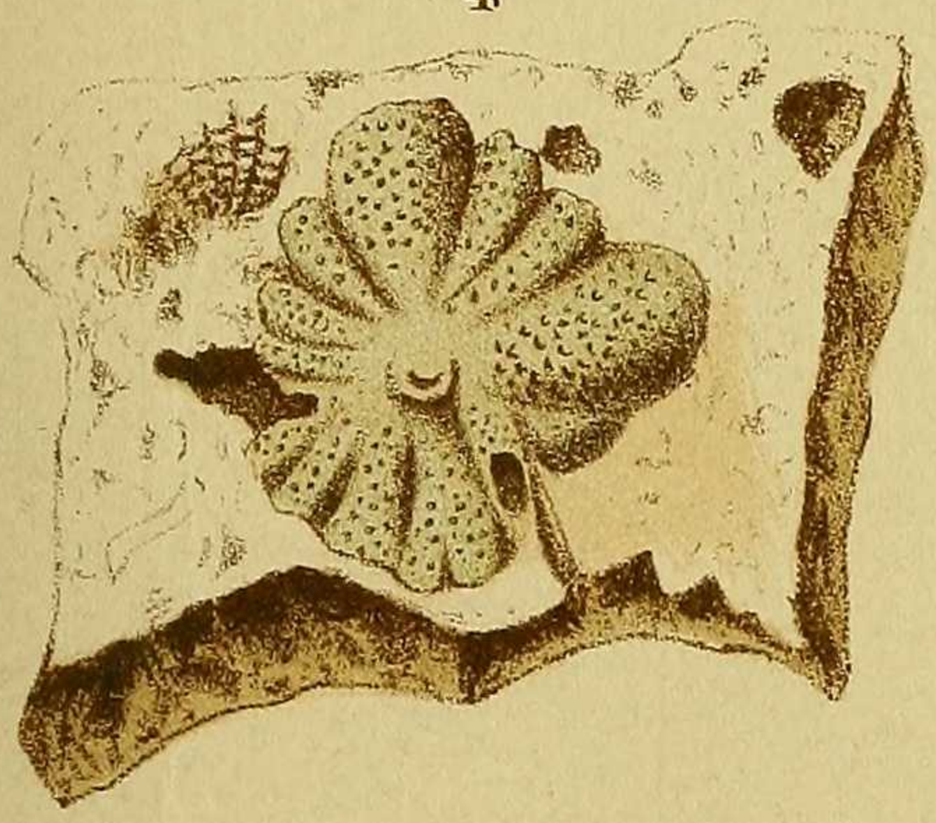

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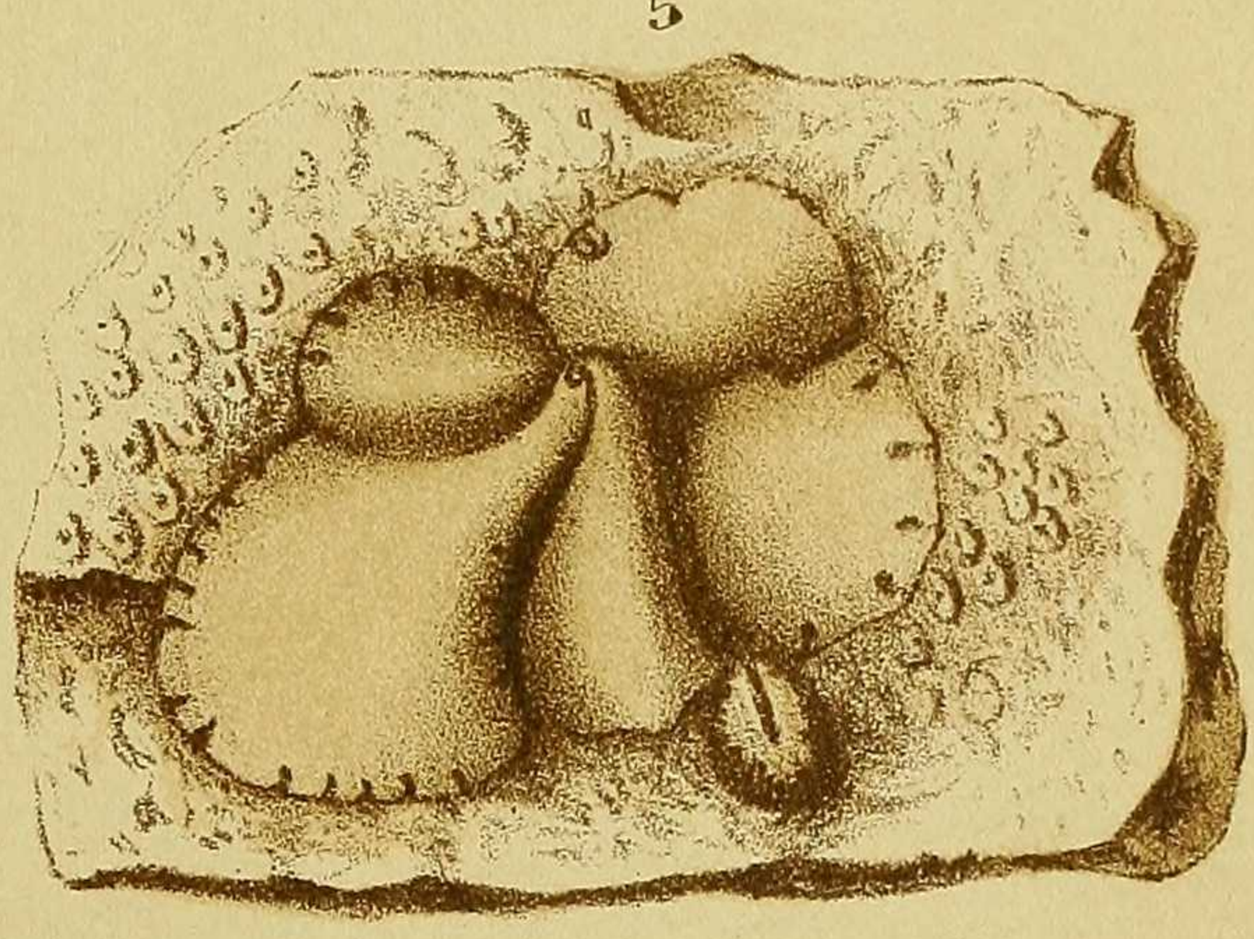

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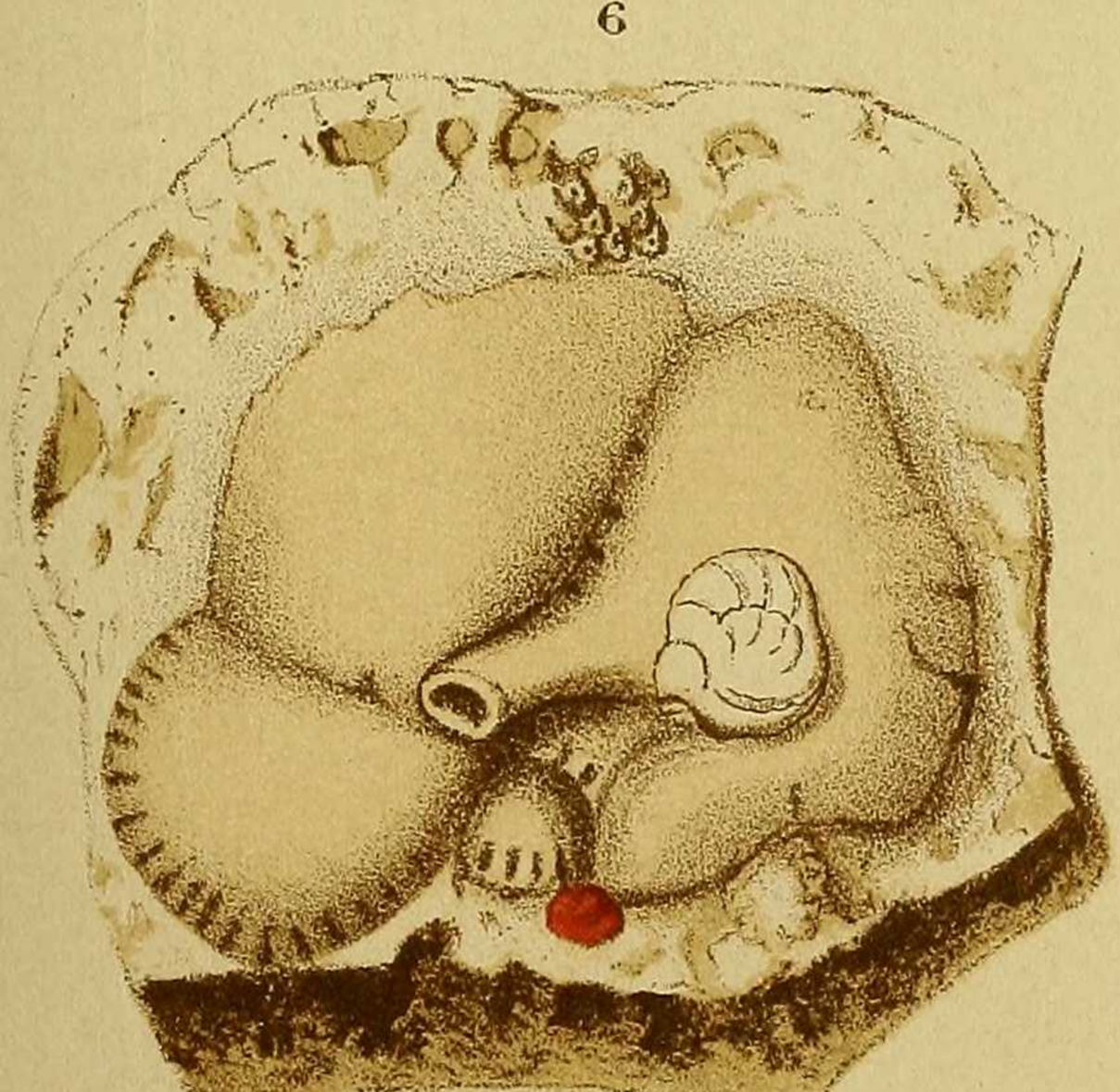

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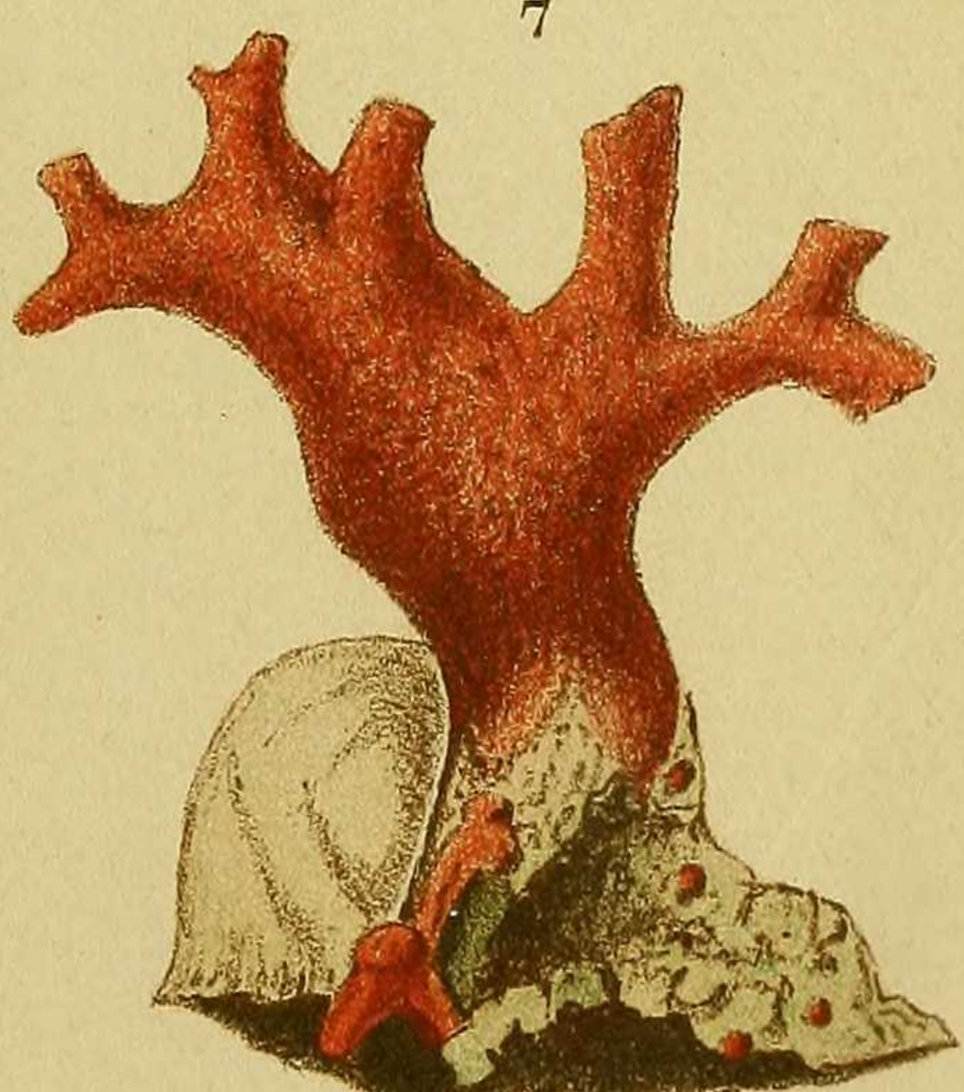

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CARPENTERIA AND POLYTREMA FROM FUNAFUTI.

Fig. 3. *Polytrema miniaceum* (Pallas), var. *involva*, nov. A section through part of a laminated mass, similar to that sometimes found intergrown with *Lithothamnion*. From trial pit, seaward face, Funafuti. × 36.

4. *Carpenteria utricularis*, Carter. A vertical section of the test, showing the papillate exterior and chambers partly filled with sponge-spicules. × 36.

5. *Carpenteria monticularis*, Carter. A vertical section taken through the base of the test, showing the smooth external surface and coarse and fine tubuli. × 36.

6. *Cycloclypeus Carpenteri*, Brady. A full-grown specimen of the megalospheric form (A). × 6.

7. *C. Carpenteri*, Brady. A vertical section of the test, showing the extraordinary thickness of the secondary layer of shell. The thin flange-like periphery has broken away. × 10.

Plate 3.

Fig. 1. Two series of *Cycloclypeus Carpenteri*, Brady, showing the various stages of growth in forms A (megalospheric) and B (microspheric) respectively. ½ nat. size.

2. The central portion of a microspheric form of *C. Carpenteri*, Brady, cut a little out of the median plane, showing an interesting resemblance in its commencement to *Heterostegina*, to which genus it bears some relationship. × 36.

3. A half-grown specimen of the microspheric form of *Cycloclypeus Carpenteri*. × 5.

4. A megalospheric form of *C. Carpenteri* in median section. The shell has been badly broken at various stages of growth and repaired again. × 16.

5. The sarcode of *C. Carpenteri* (form A). × 10.

6. A microspheric form of *Heterostegina depressa*, d'Orbigny. × 10.

7. A megalospheric form of *H. depressa*. × 10.

Plate 4.

All magnified 5 diameters.

Fig. 1. *Carpenteria balaniformis*, Gray. Lateral aspect. Off Funafuti, 115–200 fathoms.

2. *C. balaniformis*, Gray. Oral aspect. Off Funafuti, 115-200 fathoms.

3. *C. utricularis*, Carter. Coloured by an alga. Lateral aspect. 8 fathoms. Off Funamanu (Beacon Id.).

4. *C. utricularis*, Carter. Coloured by an alga. Oral aspect. Off Funamanu. 80 fathoms.

5. *C. monticularis*, Carter. Oral aspect. Off Funamanu. 80 fathoms.

6. *C. monticularis*, Carter. Oral aspect. Off Funamanu. 80 fathoms.

7. *Polytrema miniaceum* (Pallas). Off Funamanu. 150 fathoms.

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