

X.—On some Foraminifera from the North Sea, etc., dredged by the Fisheries Cruiser "Goldseeker" (International North Sea Investigations—Scotland). v. On *Thurammia papillata* Brady: a Study in Variation.

By EDWARD HERON-ALLEN, F.L.S. F.Z.S. Pres. R.M.S.,  
and ARTHUR EARLAND, F.R.M.S.

(Read November 21, 1917.)

PLATES XXVI.—XXX.

THE genus *Thurammia* being essentially of deep-water habit is not represented at all in the majority of the "Goldseeker" dredgings, which are from shallow water adjacent to the Scottish coast-line. In some of the dredgings from the deeper areas of the North Sea and off the west of Scotland, however, *Thurammia* occurs in such abundance and variety as to furnish material sufficient for a critical study and revision of this interesting genus.

A brief synopsis of the published literature of *Thurammia* appears to be a desirable preliminary to our own remarks on the genus, which was established by Brady in 1879 (Ref. 2), for the reception of specimens discovered in material dredged by the "Challenger." Three species, *T. papillata*, *albicans*, and *compressa*, were described, but only the first and last were figured. The genus had probably attracted Brady's attention long previously,

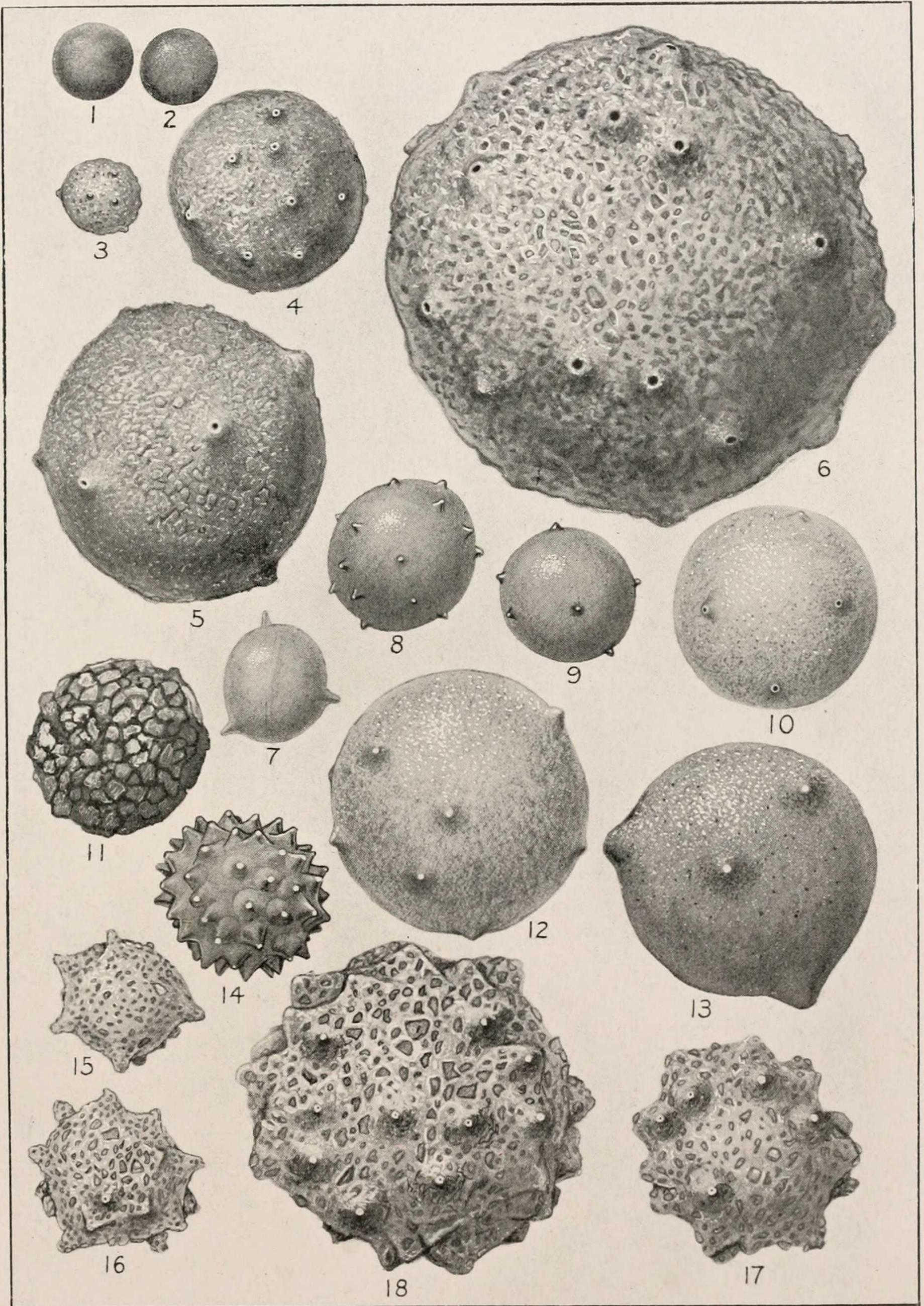
---

EXPLANATION OF PLATE XXVI.

FIGS.

- 1, 2.—Chitinous spherules, the earliest free stage of *Thurammia papillata*. Papillæ absent.
- 3-6.—*T. papillata* Brady = "Orbuline *Lituola*" of Carpenter. Typical arenaceous spheres in various stages of growth.
- 7, 8.—Chitinous individuals. Colour, purple. Papillæ imperforate.
- 9.—Sphere type. Chitin and cement. Colour, metallic copper. Papillæ imperforate.
- 10.—Sphere type. Built of grey micaceous mud. Papillæ minute, sometimes imperforate or absent.
- 11.—Sphere type. Large sand-grains and black cement. Papillæ absent or very inconspicuous.
- 12, 13.—Sphere type. Finely arenaceous, with imperforate papillæ.
- 14.—*T. papillata* var. *castanea* var. nov. Purple chitin, with imperforate papillæ.
- 15-18.—Ditto. Arenaceous specimens in various stages of development. The prominent papillæ are frequently closed at the apex with fine cement.

All specimens magnified 45 diameters.



J. R. Ford, del.

Thurammina.

for he identifies his species *T. papillata* with the "Orbuline *Lituola*" figured by W. B. Carpenter in "The Microscope" [5th ed. 1875] (Ref. 1).

Brady did not make any attempt in the paper of 1879 to deal with the affinities of *Thurammia*, but in a later paper of the same series published in 1881 (Ref. 3), in which he adumbrated the classification of the Order which was to be adopted in the "Challenger" Monograph, he assigned the genus to the family Lituolidæ. The generic definition of *Thurammia* as published in 1879 is short, but, with a few modifications, sufficient for our present more extensive knowledge of the genus:—

"*Thurammia* (*θυρίς*: a cell; *ἄμμος*: sand). Test free or adherent, either consisting of a single rounded chamber, sometimes enveloping a similar one of smaller size, or of two or more (apparently) independent chambers adhering to each other. Texture thin, arenaceous or chitino-arenaceous. Surface beset with numerous perforate nipple-shaped protuberances."

Brady is less happy in his specific description, having apparently failed (perhaps owing to paucity of material) to realize the essentially unstable character of the organism.

A more prolonged study of the subject, aided by a more liberal supply of specimens, would probably have resulted in the suppression of the two species, *T. albicans* and *compressa*, or at any rate in their reduction to varietal rank, for he admits their close relationship to the type species *Thurammia papillata*.

Butschli in 1880 (in Bronn's "Klassen und Ordnungen des Thierreiches") (Ref. 4) reproduces two of Brady's (1879) figures of *T. papillata* (Ref. 2, pl. v, figs. 4 and 6), but ranks the genus with *Psammosphæra*, *Storthosphæra* and *Sorosphæra* in a supplement to his sub-family Globigerinæ.

Carpenter, in the 6th ed. of "The Microscope," published in 1881 (Ref. 5), reproduces the same figures as in 1875, but assigns them to *Thurammia papillata*, "a remarkable imitation of the Orbuline type," and refers to the neatness with which the component sand-grains of small and uniform size are cemented together so as to present a smooth surface both inside and out. His knowledge of the genus was apparently confined to the globular type with prominent nipple-shaped protuberances bearing orifices. In the 8th ed. (1901) (Ref. 31) the "Orbuline *Lituola*" of 1875 has been assigned to Brady's species *T. papillata*.

Uhlig, in 1882 (Ref. 6), refers to Brady's recently described genus *Thurammia*, and records that he had observed in the previous year shells of similar construction in his washings of material from the Jurassic of Brunn. He promises a further study of these forms, which does not appear to have been published in any of his articles which are known to us, or to have been referred to by other authors.

In 1882 Rudolf Haeusler, whose name must always be associated with a genus to which he contributed so much interesting literature, commenced his observations with a note (Ref. 7) in which he recorded the occurrence of Brady's three species, *T. papillata*, *compressa* and *albicans*, from the Oxfordian of Aargau, and announced two new species, *T. tuberosa* and *canaliculata*, of which, however, no figures or descriptions were given.

In 1883 he published two further papers dealing largely with fossil representatives of the genus (Refs. 8 and 9). He remarks that the Jurassic *Thurammia* differs but little from the recent forms described by Brady, some of the specimens still showing the peculiar yellowish colour.

A further statement that the "recent *T. papillata* is very variable" would seem to point to a knowledge of recent material beyond the published information available at this date, for the figures of Brady and Carpenter do not illustrate any great range of form. (But see our note *infra* upon his paper of 1890.) Haeusler records the finding of a few polythalamous specimens similar to Brady's example, and enlarges our information as to the type species *T. papillata* by some excellent figures of large and coarsely papillate specimens of irregular shape such as occur frequently in some of the "Goldseeker" material, also specimens with produced tubular apertures.

With less reason he creates a new species, *T. hemisphærica*. Test finely arenaceous, very thin, transparent, invariably fixed, nearly hemispherical, monothalamous, with a few indistinct papillæ placed around the margin. Haeusler claims that it is readily distinguishable from fixed varieties of *T. papillata*, but on what appear to be very insufficient grounds.

In the same year, 1883, Haeusler published in English a valuable paper on the Jurassic varieties of *T. papillata* (Ref. 10), illustrated with a plate containing more than thirty figures. The extreme variability of the species was for the first time recognized and suitably illustrated. The paper contains many valuable details as to the distribution and zoological associations of the genus, and it is of great interest to find that such characteristics have remained unchanged throughout long geological epochs. Thus Haeusler records that fossil specimens occur most abundantly in beds full of siliceous sponges, an association which exists to-day, for all the "Goldseeker" dredgings in which *Thurammia* occurs plentifully are marked by an abundant sponge fauna, while dredgings of similar depth in adjacent areas devoid of sponge fauna are also marked by paucity or absence of *Thurammia*. The reason of the association is the more obscure as *Thurammia* does not, except under very exceptional circumstances, employ spongal detritus in the construction of its tests. Haeusler also records that *T. papillata* is found in greatest numbers and in the finest condition in the

beds with abundant *Hyperammia* (*H. vagans* Brady). The same association is noticeable in most of the "Goldseeker" dredgings; wherever *H. vagans* and *H. ramosa* form a considerable percentage of the rhizopodal fauna *Thurammia* occur in numbers. The association of the *Hyperammia* with a sponge fauna is more readily understood, as both species of *Hyperammia*, and especially *H. ramosa*, employ sponge spicules largely in the construction and armament of their tubes.

Haeusler states that "in comparing a great number of specimens of different ages and localities we find that the species can be divided into a number of groups, each of which contains some characteristic and often remarkably constant varieties. But owing to their great variability most of them can be connected through intermediate forms, forming thus a single series from the simple spheroidal to the most complicated types. . . . As the distribution of the recent *T. papillata* is world-wide, its oldest fossil representatives seem to be present in the deep sea sediments all over Europe in countless modifications, many of which have not been found in a recent state. On the other hand, the globular large varieties with small papillæ and very finely arenaceous tests of our existing seas are not known in a fossil condition."

Haeusler records that the tests of all the Jurassic specimens of *T. papillata* are very thin, composed of small grains of quartz sand, neatly fitted together, and united by a colourless brownish or yellow cement. It would thus appear that his fossils, although presenting an equal or even greater range of external form than recent specimens, were more limited in their range of structure. The chitinous tests, devoid of all arenaceous investment which occur in many "Goldseeker" dredgings, do not appear to be represented in the Jurassic, unless, as seems probable, Haeusler is referring to this type of shell when he describes certain specimens as hyaline, a form of structure unknown in recent *Thurammia* and incompatible with all we know of the genus.

The Jurassic specimens of *T. papillata* were divided by Haeusler into eleven groups, but without varietal names, and references for each group are given to figures on the plate accompanying the paper. All the groups occur among our "Goldseeker" material.

The same year, 1883, was marked by the publication of Haeusler's paper on the new genus *Thurammiaopsis* (Ref. 11). He had already foreshadowed it by a reference to the single species as *Thurammia canaliculata* in the previous year (Ref. 7). Haeusler's type-specimens, if they were ever brought to this country, have apparently disappeared, at any rate enquiries in all likely quarters have proved unfruitful. We are therefore compelled to fall back upon his published description and figures, supplemented by the further information contained in his later reference to the same form in 1890 (Ref. 21). No subsequent discovery

of Haeusler's sub-genus *Thuramminopsis* has ever been recorded either in the recent or fossil state.

*Thuramminopsis* is separated by its author from *Thurammia* mainly on the existence on the exterior of the shell of strictures corresponding with an internal rectangular tube system, which he says reminds him of the siliceous scaffolding of the hexactinellid sponges. From the fact that the tubes often open to the outside he was of the opinion that they were not merely to support the very brittle shell, but also served in the nourishment of the animal, presumably acting as the communication between the contained protoplasmic body and the surrounding medium. But he admits that he was not in a position to confirm this latter theory, as, owing to the bad condition of the fossil shells, he was unable to observe any internal openings to the tubes. He admits the great similarity existing between *Thuramminopsis* and the Jurassic varieties of *Thurammia papillata*, indicating their near relationship, and in the later paper (1890) he lays less stress on the tube system, and his figures are much more irregular and variable, and display a closer affinity to the large irregular specimens of *T. papillata* than his original figures.

In 1884 Brady published his great "Challenger" Monograph (Ref. 12), in which the three species, *T. papillata*, *albicans* and *compressa* described in 1879 (Ref. 2) are more fully dealt with, and for the first time he figured the species *T. albicans*. He adds very little to the information accumulated in the interim by other authors, merely referring to Haeusler's and Uhlig's discoveries without figuring any of the abnormal and irregular types which Haeusler in particular had discovered, and which presumably did not come under his notice when dealing with the "Challenger" material.

In 1885 Haeusler records (Ref. 13) the occurrence of *T. papillata* from the zone of *Terebratula impressa* of Aargau, but adds no further information, and his figure represents only a fragment.

In 1886 Joseph Wright (Ref. 14) lists *T. papillata* as occurring among the Cretaceous Foraminifera of Keady Hill, and published a good figure of the regular spherical type. This is the first Irish Cretaceous record, and the species is described as rare.

*T. papillata* appears among the species recorded by Brady in his "Synopsis of British Recent Foraminifera" (Ref. 15) published in 1887. Two localities only are furnished, one Scotch and one Irish, ranging between 38 and 110 fathoms—very shallow water for the species.

In 1887 Haeusler records (Ref. 16) delicate spherical tests of *T. papillata* from Hauraki Gulf (New Zealand) shore gatherings, "with short papillæ distributed irregularly all over the surface resembling the passage form of *T. albicans* and *T. papillata* from the upper Jurassic strata."

In 1888 Agassiz refers (Ref. 17) to the occurrence of *T. papillata* in his "Three Cruises of the 'Blake,'" and reproduces one of Brady's figures.

In 1889 Sherborn and Chapman record (Ref. 18) *T. papillata* for the first time from Tertiary beds, from the London Clay of Piccadilly, and figure a spherical type with few irregular papillæ.

In the same year Dreyer, in his Monograph on the organisms with "pylom," or papillate orifices (Ref. 19), refers to Brady's abnormal figure of *T. papillata* (Ref. 12, pl. xxxvi, fig. 12) (in which an internal shell connected by tubes with the outer sphere is figured), as a noteworthy exception to the rule of construction upon which he founds the theory of concentric skeleton systems set forth in the work. He describes Brady's specimen as "the effort of a thalamosphere in the direction of concentric development, but no more, as may be sufficiently concluded from its incomplete development and its quite isolated occurrence."

In 1890 Haeusler published an important Monograph upon the zone of *Ammonites transversarius* of the Swiss Jurassic (Ref. 21). In dealing with *Thurammia* he states that in the Upper Jurassic *T. papillata* is uncommonly variable, and even goes to the extent of stating that it is "incontestably the most variable of all animal species; it is in fact difficult to convince oneself that the countless number of forms can all belong to a single species. The recent *T. papillata* is characteristically much more constant." As we shall see later on, Haeusler's conclusion must have been based largely on the few published figures of recent *Thurammia*, and he can have had no experience of the endless variations observable in recent material such as has passed through our hands. It will be remembered that in his 1883 paper (Ref. 8) he observed that "the recent *Thurammia* is very variable." It becomes clear that his observations upon a more extended range of material had led him to alter his views. Dealing with *Thurammiaopsis* he defines the difference between this and *Thurammia* as: (1) *Thurammia* always possesses a single hollow chamber; (2) *Thurammiaopsis* possesses an internal rectangularly intersecting system of broad cylindrical tubes which correspond with funnel-shaped depressions upon the outer surface of the shell; but he admits the existence of typical individuals devoid of tubes, and also of the surface depressions, which may be taken as passage forms between the two genera. He indicates a further difference between the two genera, in the surface texture of the shell, the particles in *Thurammia* being built in as a mosaic, so that the resultant surface is quite smooth; whilst in *Thurammiaopsis* the particles are disposed more irregularly in the cement, so that the surface has a rougher appearance. But, as we shall see from the "Goldseeker" specimens, this distinction has no constant value, many unquestionable specimens of *T. papillata* having a roughly irregular surface; and

it would therefore appear from Haeusler's own admissions, coupled with our examination of a series of abnormal recent specimens, that his sub-genus *Thuramminopsis* has little, if any, value from a biological point of view, and that *T. canaliculata* should properly be regarded merely as an extreme modification of *T. papillata*.

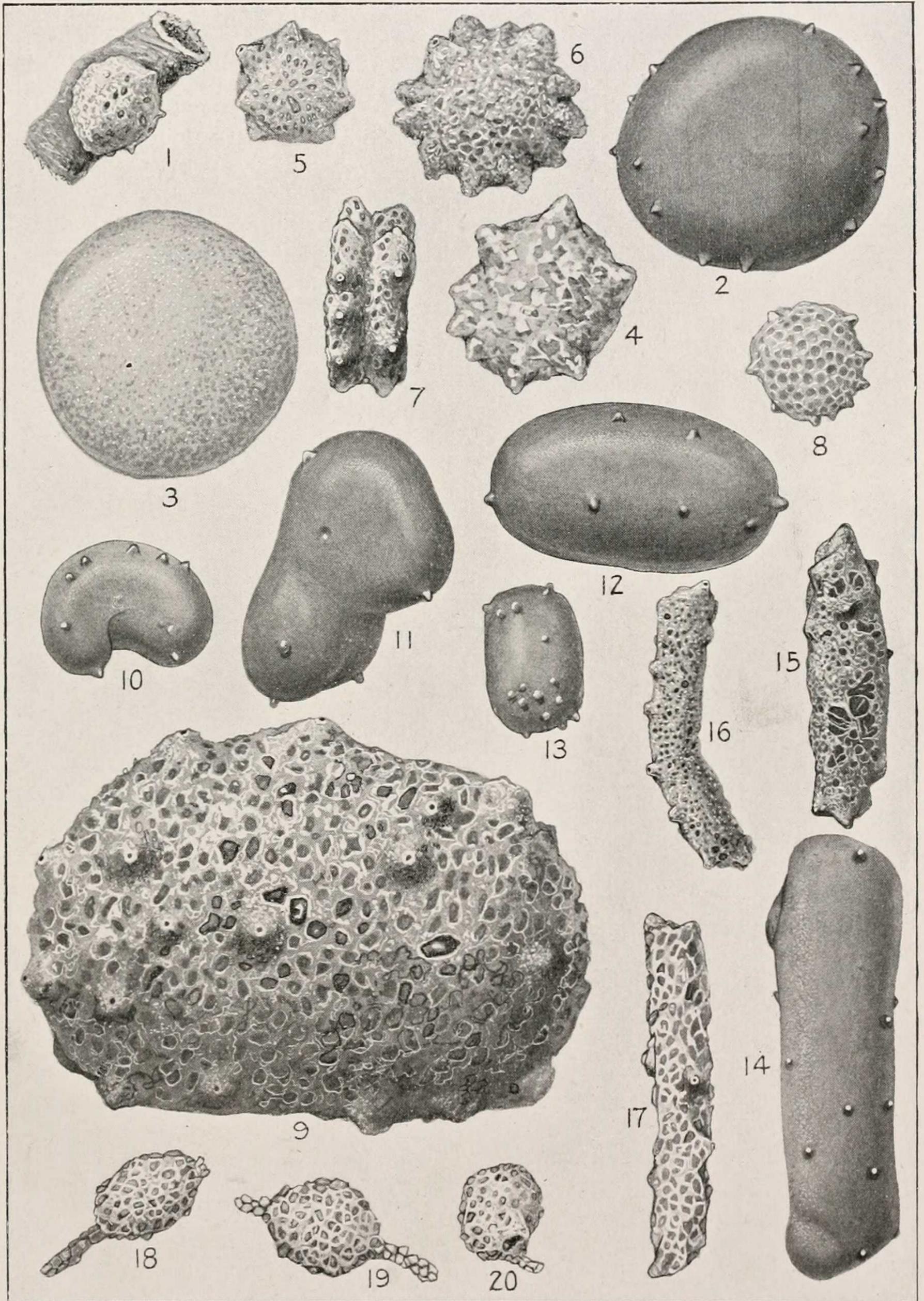
In addition to the species already described by himself and Brady, Haeusler in this paper describes and figures two new species: (1) *T. elegantissima*, characterized by the possession of semi-globular shaped chambers attached to a base of finely arenaceous texture, and with a thin glassy shell-wall, which, according to the figure, we should prefer to describe as an agglomeration of simple semi-globular chambers, destitute of actual papillæ; and (2) *T. tuberosa*, which had already been referred to as a *nomen nudum* in 1882 (Ref. 7, p. 227), and in 1885 (Ref. 13, p. 4). The latter is described as "a characteristic form directly connected with the large irregular deeply constricted varieties of *T. papillata*, differing from it in the shape of the chambers, each of which bears two papillæ placed opposite to one another; the sausage-shaped chambers are grouped in a distinctive manner which is only more or less coherent. In only a single case were more than two papillæ observed on a single chamber." Haeusler's figures represent an agglomerated mass of individuals of *T. papillata* with few but abnormally developed papillæ.

#### EXPLANATION OF PLATE XXVII.

##### FIGS.

- 1.—*Thurammina papillata*. Sessile specimen, attached to tube of *Hyperammia ramosa* Brady = *T. hemisphærica* Haeusler.
- 2.—*T. papillata* var. *compressa* Brady. Specimen with test of cement, metallic copper colour.
- 3.—Ditto. Specimen with test of grey micaceous mud; no papillæ.
- 4.—Ditto. Specimen with test built of plates of mica attached to chitinous envelope.
- 5.—Ditto. Finely arenaceous test.
- 6.—Ditto. Finely arenaceous test. Specimen with double marginal ring of papillæ separated by groove.
- 7.—Edge view of fig. 6.
- 8.—Finely arenaceous specimen, with honeycomb surface ornament. (Cf. var. *favosa* Flint.)
- 9.—*T. papillata*. Oval form. Large coarsely arenaceous specimen. (Cf. Brady (Ref. 12), pl. xxxvi. fig. 8.)
- 10, 11.—Abnormal oval specimens, with cement tests and imperforate papillæ. Colour, metallic copper.
- 12, 13.—Oval forms in copper-coloured cement; imperforate papillæ.
- 14.—*T. papillata* var. *parallela* var. nov. Specimen with test of chocolate-coloured cement; imperforate papillæ.
- 15.—Ditto. Test largely micaceous.
- 16, 17.—Ditto. Specimens with fine and coarse arenaceous tests.
- 18, 20.—*T. papillata*. Forms with few and abnormally developed papillæ. (Cf. Brady (Ref. 12), pl. xxxvi. fig. 10; and Haeusler (Ref. 21), pl. vi. figs. 12, 13, 16, 23, 25, 26.)

All specimens magnified 45 diameters.



J. R. Ford del.

Thurammina.

In 1892 Chapman records *T. albicans* (Ref. 23), of small size and very rare, in the upper zones of the Gault of Folkestone.

In 1893 Haeusler summarized his various papers (Ref. 24), and referring to *Thurammia* records that it makes its first appearance in Switzerland in the Lower Lias. In the Calcareous Beds of Aargau (l'Etage Argovienne) *Thurammia* appear in extraordinary variety. After the *Sequanien* the genus disappears almost completely. Five species of *Thurammia*—viz. *hemisphaerica*, *albicans*, *papillata*, *tuberosa* and *elegantissima*—are recorded as well as *T. canaliculata*.

In the same year Egger (Rep. 25) records *T. papillata* from the west coast of Australia as "rare" in 359 metres, and figures a compressed egg-shaped type with irregularly disposed papillæ of considerable altitude.

Howchin, in his "Census of the Fossil Foraminifera of Australia" (1893) (Ref. 26), records *T. compressa* Brady as rare in three borings of Cretaceous age.

In 1896 Goës, reporting on the Foraminifera of the "Albatross" Expedition (Ref. 27), records a single specimen of *T. papillata* from 724 fms. in the Caribbean Sea, and also figures and describes a new species, *T. erinacea*. It is described as "somewhat wrinkled, tuberculated and beset with short closely arranged spines; sometimes the spines are more scattered and very produced in length. Shape usually globular, seldom ovoid; test sometimes provided with a short neck or shaft. Colour usually grey-yellow, sometimes whitish, with black specks, some of which may be orifices. Wall more or less thin; diameter seldom beyond 0.25 mm., Pacific, 555 to 1879 fms. Not rare." It should be pointed out that Goës himself describes this form with some hesitation; the description and figure have little in common with preconceived opinions of *Thurammia*, but strongly suggest a Radiolarian origin for the specimens. Cushman, writing in 1910 (Ref. 38), takes the same view of the identity of Goës' specimens after an examination of his material, and remarks that the mounted specimens were not easily examined, but some are plainly *Radiolaria*, which are not uncommon of this form and size in the Pacific. *T. erinacea* may therefore be disregarded as far as our inquiry is concerned.

Eimer and Fickert in 1899 (Ref. 28), in their attempt towards a reorganization of the genera and species of the Foraminifera, transferred *Thurammia* to a new family, Kyphamminidæ (*κυφὸς* = tuberculate), of which it is the sole constituent, but give no opinion as to its affinities.

In the same year Egger (Ref. 29), under the singularly inappropriate name of *Thurammia splendens*, describes a new species from the Chalk Marl of the Bavarian Alps. His figures represent three entirely different forms, which, whatever their real nature may be, are certainly not *Thurammia*. The description refers

particularly to the absence of the characteristic papillæ, and both description and figures suggest to us a Radiolarian origin for the specimens.

In 1899 Flint (Ref. 30) figured *T. papillata* from various stations in the Atlantic, and described and figured two new species from the Gulf of Mexico:—1. *T. favosa*, described as “spherical, walls very thin, arenaceous, brown. Surface ornamented with a network of thin prominent ridges extending uniformly over the whole test, forming hexagonal pits. Cavity smooth, apertures numerous, small, at the end of short tubular processes from some of the points of junction of the ridges. Diameter about 0·8 mm.” 2. *T. cariosa*, described as “spherical, surface rough, as if eroded, walls rather thick, cavernous. Cavity globular, smooth. Apertures not tubular, colour a dirty brown. Differs from *T. favosa* in the thicker walls and coarser structure, the eroded rather than reticulated surface, the cavernous walls, and the non-tubular orifices. Diameter about 1 mm.” Both of Flint’s species represent well-marked and persistent types.

Chapman, in 1902 (Ref. 32), briefly summarizes the characteristics of the species and its distribution.

Rhumbler, in 1903 (Ref. 33), attempted a systematic rearrangement of the Arenaceous Foraminifera, and transferred *Thurammina* to his fifth sub-family Saccammininæ, re-naming the genus *Thyrammina*, and giving a list of six recent species.

Kemna, in 1904 (Ref. 34), theorizes on the morphological significance of the papillæ, and regards them as modifications of the tubular rays characteristic of the primitive Astrorhizidæ, and as forming a transition stage towards a truly perforate test. In the same year, 1904 (Ref. 35), Millett records and figures *T. favosa* from shallow water in the Malay Archipelago. He appears to have held strong doubts as to the rhizopodal nature of the organism, but we are fortunately in possession of his specimens and can confirm the identification. The Malay specimens are very minute, and, for their size, thick-walled.

In 1905 Chapman and Howchin, by the record of typical *T. papillata* from the Permo-Carboniferous of Pokolbin, N.S.W., extend the geographical record of the genus backward for a considerable period.

In 1906 Gough (Ref. 37) figures under the name “*Thurammina* sp.?” some small flask-shaped arenaceous forms from shallow water, “most of them being globular, but some being rather more irregular each apparently having only one aperture at the end of a very small neck.” He compares them with *Saccammina sphærica* Sars, but remarks that they are of a smaller and finer texture. Neither his figures nor description are very convincing as regards their determination as *Thurammina*. We should be inclined to refer the specimens to *Reophax difflugiformis* Brady.

In 1910 Cushman, in his work on the Foraminifera of the North Pacific Ocean (Ref. 38), records *T. papillata* and *T. albicans* only, and criticizes adversely the rhizopodal origin of *T. erinacea* Goës from that area (Ref. 27, p. 26).

In 1913 we recorded (Ref. 39) two specimens from shallow-water dredgings in the Clare Island District (Ireland), one being of the normal *T. papillata* type, and the other a chitinous variety.

In the same year J. A. Cushman described (Ref. 40) a new species, *T. papyracea*, from "Albatross" Station D. 5613, North of Celebes, 752 fms. It is defined as: "Test spherical, wall extremely thin and delicate, composed of fine sand grains, sponge spicules, and a brownish cement; apertures very small and inconspicuous. Diameter, 1.5 mm. A large species, with a paper-thin wall and very inconspicuous apertures."

Cushman's species is evidently only a pauperate modification of the sphere type of *T. papillata*.

In 1913 Dr. Ludwig Rhumbler, in one of the instalments (Ref. 41) of his monumental work (as yet unfinished, and perhaps doomed to remain incomplete, the death of the author in the present war being reported), reproduces Brady's "Challenger" figure as illustrating the formation of the secondary or outer chamber by a flow of protoplasm from the papillæ of the inner shell, the protoplasm then proceeding to collect sand-grains for the formation of an outer shell, as figured by Brady. He agrees with the theory of Kemna (Ref. 34) as to this. He has not yet actually recorded *Thurammia* from the material of the Plankton Expedition, and it does not appear in the undescribed plates which appeared in Part I. of this work in 1909.

In 1915 we recorded (Ref. 42) a single specimen from Kerimba, Portuguese East Africa (6 fms.), characterized by the virtual absence of papillæ, and another from 10–20 fms., presenting a transition form between *T. papillata* and *T. albicans*.

In 1916 we recorded (Ref. 43) small individuals of the sphere type, both arenaceous and chitinous, from Professor Herdman's West of Scotland shallow-water dredgings.

From the foregoing synopsis, which we believe contains at any rate all the important references, it will be seen that the student of *Thurammia* is not confronted by such a bewildering medley of species as encumbers other genera of the Foraminifera. Rejecting *T. erinacea* Goës and *T. splendens* Egger as organisms of doubtful identity, we are left with some nine specific divisions, or ten including *Thurammiaopsis canaliculata*. But the examination of several thousand specimens picked out from "Goldseeker" material has convinced us that in *Thurammia* we are dealing with a protean and polymorphic type, and that it is more impossible even than with other foraminiferal genera to define the characteristics and limitations of a species. Given a sufficient number of speci-

mens it is easy to select a series linking all the published species together. Haeusler appears to have formed the same opinion from the study of his fossil specimens, for he refers repeatedly to the variability and inter-relationship of the species.

We therefore propose:—

1. To retain the earliest described and *figured* species, *T. papillata* Brady, as the type of the genus, and to include under this specific name all *Thuramminæ* hitherto described and figured under various specific names.

2. Where for taxonomic reasons further classification is required, to utilize already published specific names in a purely varietal sense.

3. To abandon certain specific names which are of no value even for varietal classification.

4. To form certain new varietal distinctions for groups which have not hitherto been described or adequately separated from other groups.

Before proceeding with our survey it will be useful to indicate a few stages in the life-history of *Thurammina* ascertained from the examination of numerous sections and balsam-mounted specimens, as the observations throw considerable light on the subsequent appearance of the individuals and their development, and will therefore assist us in our classification.

*Thurammina*, like all the Arenacea, is a benthic organism. Although from its spherical form, isomorphous with *Orbulina* and many Radiolaria, it might be surmised that it was suited for a pelagic existence, there are no records of its occurrence in this condition even in those early stages before it acquires the arenaceous investment which marks the mature stage of growth, and which of course could only be secreted by a benthic organism. But the initial stages of the organism are passed in a chitinous envelope, and we consider it not improbable that a more careful examination of tow-nettings from suitable localities may result in the discovery of pelagic individuals in the chitinous condition which, as we shall demonstrate, is frequently retained until the organism has attained its full development in size, and has acquired the characteristic oral papillæ.

On sectioning a number of specimens of *Thurammina*, and especially in the case of *T. cariosa* Flint, individuals will be found in which the central cavity contains a number of "gemmules," or minute bodies of a spherical or sometimes of a pointed oval shape and dark shining appearance, loosely aggregated together or attached to the inner wall of the shell (Pl. XXIX, fig. 8). Other specimens will be found with the cavity more or less filled with a reddish mass, like raspberry jam, consisting of similar gemmules, but of larger size (Pl. XXIX, figs. 9, 10). These gemmules are quite different in appearance from the dark protoplasm with metaplastic

bodies found in other shells, and we have no doubt that they represent the initial stages of reproduction. In other specimens it will be observed that a limited number of the gemmules have increased in size at the expense of the rest, and have developed into small spherules of chitin, more or less filling the cavity of the specimen, according to their number, which varies in observed specimens from a single chitinous spherule to a crowded mass filling the central cavity (Pl. XXIX, fig. 11). Sometimes a single large chitinous sphere will be found occupying the greater portion of the central cavity. At this stage personal observation necessarily ceases, and we must assume that the chitinous spheres are set free by the resorption of the parent test and commence an independent existence. While in the test the spherules are always chitinous, and present no aperture or sign of papillar formation, nor, as a rule, are any protoplasmic contents visible through the chitin, which varies in colour from almost glassy transparency to a deep violet or purple colour. The colour may be partly due to the thickness of the chitinous wall, which is very variable, ranging from a mere film, so thin as to be collapsible, and to give diffraction colour effects, to a wall having an appreciable thickness, as seen in optical section.

The life-history of the spherules after their liberation is at present obscure. As already stated, we think it not improbable that such spherules will be discovered in pelagic gatherings, and so furnish evidence that *Thurammia*, like its isomorph *Orbulina*, passes the initial thin-walled stages of its career at, or near, the surface, before sinking to the bottom to complete its life-history with an agglutinated shell-wall. The formation of gemmules and spherules has been observed by us in *T. papillata*, *T. albicans*, and *T. cariosa*, and there can be little doubt that it extends to all the other varieties.

The spherules range in size between 0·01 mm., the smallest measured, and 0·2 the largest. The smallest free living chitinous spheres measured were 0·2 mm., but smaller collapsed specimens have been observed. The smallest arenaceous sphere measured was only 0·12 mm.

But although our pelagic theory must await confirmation, the fact remains that such chitinous spherules (Pl. XXVI, fig. 1) are abundant in the fine floated material from the "Goldseeker" stations where *Thurammia* occurs in any numbers, and their subsequent life-history can be followed with some certainty. Continuing to increase in size, they gradually acquire oral papillæ, often marked at the outset by surface perforations only; they secrete investing walls of varying characters, although this arenaceous investment is often postponed until the organism has acquired a comparatively mature condition and assumed those protean shapes which baffle taxonomy. This early and continued

chitinous condition is, in our opinion, the key to the problem of relationship between the groups, and is responsible for the protean forms which have been figured, especially by Haeusler, under the name "*papillata*." The flexible chitinous membrane lying in contact with other organisms, and under the influence of many conditions beyond our imagination, responds to the stimuli, collapses and expands according to its environment, and develops abnormal forms of growth. No other explanation will account for the protean forms obtained from the "Goldseeker" material.

We shall have occasion to refer to the occurrence of associated tests—usually in pairs, but occasionally in groups of three or even four individuals. There is little or no evidence that this phenomenon is in any way connected with the reproduction of the animal. We agree with Brady that it is merely a case of association of two or more individuals which have come into contact with each other, and continued their growth side by side as attached specimens. There is no resorption of the walls of the test at the point of contact to provide free transfusion of the protoplasm between the individuals. Neither sections nor balsam-mounted specimens give any evidence of channels of communication between the two tests beyond the normal papillar openings. It is noteworthy that such associated pairs are usually of identical size, though Brady (Ref. 12) figures an abnormal association, consisting of one large and two smaller individuals (pl. xxxvi, fig. 15). In the variety *T. cariosa* it is also to be observed that the associated pairs combine to form a common spongy layer, which gradually fills up the groove separating the two spheres (Pl. XXIX, fig. 6).

It is worth recording that, in our experience, the individuals of associated pairs are always identical as regards variety. We have no record of any mixed pairs, although instances occur in which *included* shells are of a different nature to the outer sphere. These two observations, and the further fact that in our new variety, *sordida*, the associated individuals of a pair are sometimes bound together by a collapsed chitinous membrane, which probably in life contained both individuals as in a common cyst or bag, may, perhaps, be taken as some evidence towards regarding the association as a sexual process, or even as an alternation of generations. But it would not, in our opinion, be safe to base any deductions upon such isolated records.

Of quite different significance and much greater variety are the instances of budding. Very few cases of budding have come under our observation, but we figure two instances, in one of which the parent sphere of an irregular *haeusleri* type is seen in the act of forming several small individuals, which are but loosely attached to the parent (Pl. XXIX, fig. 16). In the other a regular *castanea* sphere has budded a smaller sphere at one pole, and an irregular test at the other (Pl. XXIX, fig. 17).

*Thurammia papillata* Brady.

Type, "Orbuline *Lituola*" of Carpenter (Refs. 1 and 5).

Plate XXVI, figs. 1-13.

In the figure of an "Orbuline *Lituola*" figured by Carpenter in 1875 (The Microscope, Ref. 1), we have the original type on which Brady subsequently founded (Ref. 2) his species *Thurammia papillata*, and the figure fortunately represents an organism of very constant shape and of world-wide distribution, and is therefore peculiarly fitted to retain its position as the central type of the genus. Carpenter's figure represents a perfectly spherical thin-shelled test built up of many minute sand-grains, accurately fitted together in a mosaic by a ferruginous cement which gives to the test a well-marked colour, ranging between pale lemon and dark brown, but is never present in sufficient quantity to mask the constituent sand-grains or give a Trochammine finish to the surface, which is always slightly rough and unpolished. The surface of the sphere is beset with a variable number of papillæ, projecting but little from the surface and distinctly perforate. This original figure, resembling our figs. 3-6, Pl. XXVI, we propose to retain as *T. papillata* Brady type. It is to be regretted that Brady, although identifying his species *papillata* with Carpenter's earlier published figure, did not adequately figure Carpenter's type either in 1879 or 1884. His figure 7 (Ref. 12) was perhaps intended to represent the typical sphere type, but really represents a characteristic form with imperforate papillæ to which we refer *post*. Brady's other figures represent more or less abnormal forms.

Starting from this central type, variation begins and progresses in many directions, according to the nature of the shell-wall, the number of its papillæ, their shape and size, etc.

VARIATION IN WALL OF SPHERE. CHITINOUS AND  
SUB-CHITINOUS FORMS.

At "Goldseeker" Stn. IX B, 61° 34' N. 2° 9' E. (330 metres), where the type is fairly frequent, we find an interesting series of specimens in which the original chitinous wall is retained without traces of arenaceous investment. They are usually of a violet or purple colour with characteristic papillæ, and generally without visible protoplasmic contents (Pl. XXVI, figs. 7, 8). The chitin varies considerably in thickness, but is usually so thin that the sphere has more or less collapsed in drying. Such specimens occur in less numbers at other stations.

Proceeding from these purely chitinous forms, some specimens of which equal in size the normal *type* as found at this Station, emerge a whole series in which an investing shell has been secreted without the use of constituent visible sand-grains. Such

specimens of course pass by imperceptible degrees into the *type*, but two distinct forms are worthy of note as characteristic of this Station, although occasionally found elsewhere. In the first, the wall of the sphere is smooth, and sometimes rather polished, constructed of homogeneous cement, ranging from bright copper to dark chocolate in colour (Pl. XXVI, fig. 9). The second is steel-grey in colour, and with a glazed surface and less prominent, or sometimes hardly perceptible, papillæ. The wall of the test in the last form is apparently thickened with micaceous mud, the particles of which are infinitely small (Pl. XXVI, fig. 10). Yet another form found at this Station and elsewhere presents a sphere almost devoid of papillæ, and nearly black in colour. The shell is constructed of minute and angular sand-grains, giving a glistening appearance to the test. The cement is dark and liberally used (Pl. XXVI, fig. 11).

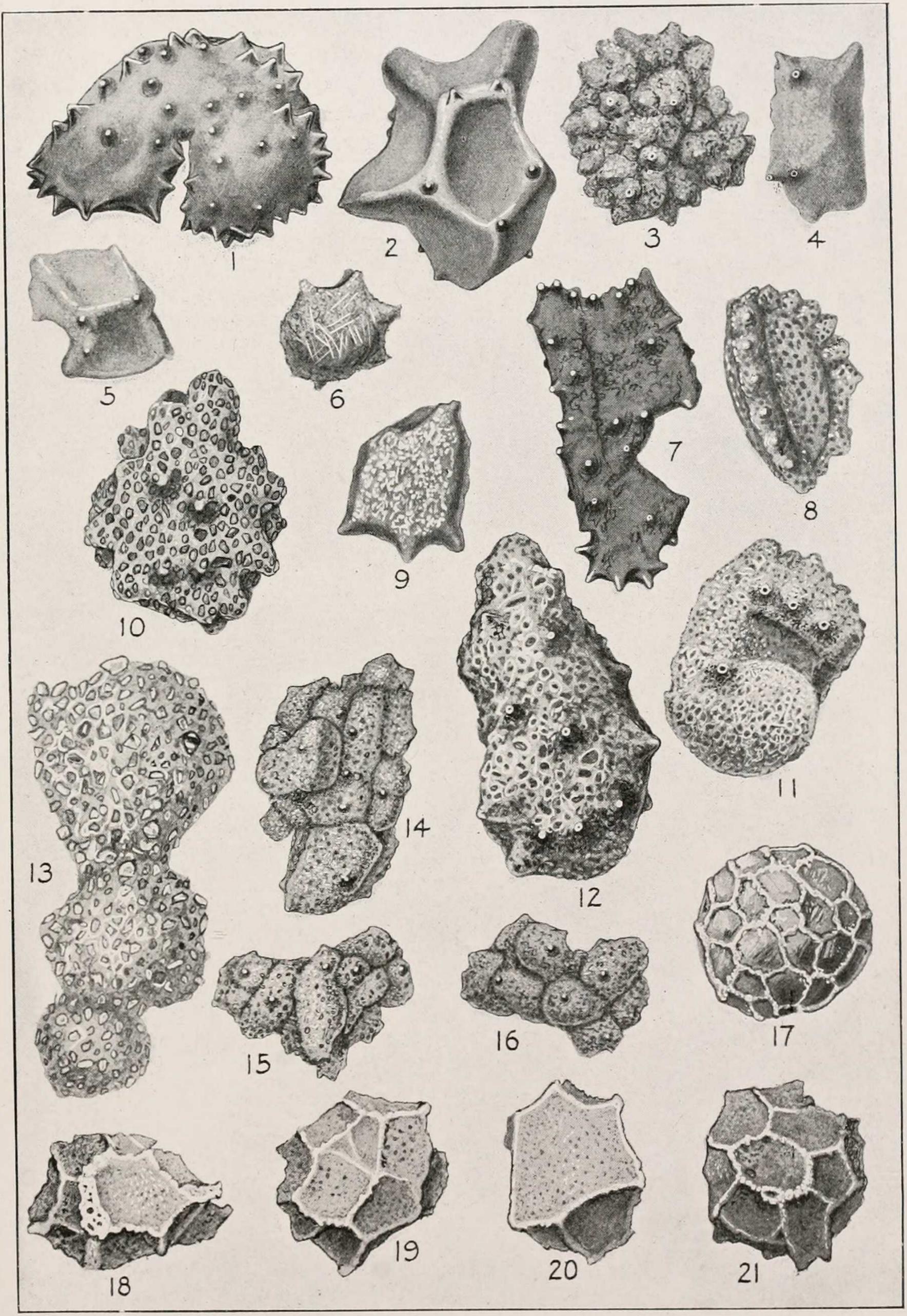
Brady's figure 7 (pl. xxxvi, Ref. 12) represents a variation which is of fairly frequent occurrence wherever the *type* prevails, and in which the characteristic papillæ are imperforate. In the "Challenger" figure the imperforate papillæ are prominent, but this feature is subject to great variation, and in many of the "Goldseeker" specimens the imperforate papillar areas lie practically flush with the surface of the sphere, from which they can be distinguished owing to a difference in colour, which may be due either to a reduction of the thickness of the wall in this area, or to its lesser homogeneity and absence of cement (Plate XXVI, figs. 12, 13). These imperforate papillæ and papillar areas are, no doubt, permeable to protoplasm, and Kemna (Ref. 34) regards them as analogous to the tubules in the wall of the perforate Foraminifera. It may be remarked that imperforate papillæ and papillar areas are indicated on the interior of the sphere by depressions similar to those on the *type*, but not perforating the shell-wall.

#### EXPLANATION OF PLATE XXVIII.

##### FIGS.

- 1-12.—*Thurammia papillata* var. *haeusleri* var. nov.  
 Figs. 1.—Compressed specimen, with numerous imperforate papillæ. Test of clear brown chitin.  
 „ 2.—Test of cement; pale chocolate colour; papillæ imperforate and few in number.  
 „ 3.—Arenaceous specimen, largely micaceous; numerous papillæ, some perforate.  
 „ 4, 5.—Chitinous specimens.  
 „ 6.—Specimen utilizing sponge-spicules largely for construction of test.  
 „ 7.—Highly compressed dark chitinous specimen.  
 „ 8.—Arenaceous specimen. Imperforate papillæ arranged in rows down three angular edges.  
 „ 9.—Specimen with micaceous test on chitinous foundation.  
 „ 10-12.—Coarsely arenaceous specimens.  
 13-16.—*T. papillata*. Aggregated individuals. (Cf. *T. tuberosa* Hæusler.)  
 17.—*T. papillata* var. *favosa* Flint. Chitinous form.  
 18-21.—*T. papillata* var. *murata* var. nov.

All specimens magnified 45 diameters, except fig. 17, which is 90 diameters.



Thurammina.

J. R. Ford, del.

*Thurammia papillata* var. *castanea* var. nov.

Plate XXVI, figs. 14-18, and Plate XXIX, fig. 17.

As opposed to the last described form, in which the imperforate papillæ are practically flush with the wall of the sphere, we have from many localities a variation which may be referred to Hæusler's figure 7 (Ref. 21, pl. vi), and for which we propose the varietal name *castanea*, because the shell is covered with large conical papillæ, set closely all over the sphere like the spines on a horse-chestnut. Such specimens often attain large size and a comparatively coarse arenaceous investment, but minute specimens are also to be found, also all transition forms, from the purely chitinous to coarsely arenaceous. Brady's curious figure 9 (Ref. 12, pl. xxxvi.) may probably represent a variation of this form, in which the numerous spinous papillæ are confined to one half of the sphere. Specimens intermediate between the smooth and spinous spheres in all stages of size are to be found. It must be distinctly understood that we use varietal names in a taxonomical sense only. They have no biological significance.

#### VARIATIONS FROM THE SPHERE TYPE.

Turning to variations in shape from the sphere we find ourselves in a maze of forms, some of which can be dismissed with brief notice, while others call for more attention.

*Thurammia hemisphærica* Hæusler (Ref. 9, pl. iv, fig. 14), may, we think, be dismissed with scant ceremony and the specific name discarded. *Thurammia* in the attached condition are, in our experience, of rare occurrence, but like many Arenacea, *T. papillata* at times assumes the sessile condition, and as such becomes, of course, hemispherical. We have met with such specimens (Pl. XXVII, fig. 1), but see no object in retaining even a varietal name for sessile individuals.

*Thurammia papillata* var. *compressa* Brady.

Type, *T. compressa* Brady (Refs. 2 and 12).

Plate XXVII, figs. 2-8.

*Thurammia compressa* Brady is in a different case, and to some extent a distinctive form and worthy of retention as a varietal name. The variety is characterized by the presence of comparatively large papillæ, situated round the marginal edge of a flattened sphere, and originates in the compression of the *type* sphere at the two poles and the suppression of the papillæ, except those on the equatorial ring, which become largely developed. Such suppressions of the papillæ would result as a matter of course from compression of the sphere, as the papillæ on the marginal edge of

a benthic organism would have readiest access to the environmental mud. Kemna (Ref. 34) regards these marginal papillæ as analogous to the ray-like arms of the *Astrorhizidæ*. Both features are so obviously due to the same cause that the analogy seems superfluous. As with the spherical type, the papillæ vary enormously in development, and are sometimes entirely suppressed.

Specimens may often be found in which the papillæ are not confined to the marginal ring, but are scattered more or less over the surface of the disc. Such specimens are not strictly referable to the var. *compressa*, but could be more correctly described as compressed individuals of whatever type they may belong to structurally. We have records of the occurrence of such compressed individuals in nearly every group. They probably arise owing to the collapse and compression of an individual while still in the chitinous condition, and the subsequent development of an arenaceous investment over the collapsed test.

Among the many published figures referred to *T. papillata* some may be dealt with summarily. Thus Brady's figure (Ref. 12, fig. 8, pl. xxxvi) represents an oval variation of the sphere which is of fairly frequent occurrence (Pl. XXVII, figs. 9-13). Such abnormalities may perhaps originate in the fusion of two individual gemmules. The oval may become more produced at the poles so as to form a parallelogram with rounded extremities, and so pass imperceptibly into an elongated tubular type for which we propose the varietal name *parallela*.

*Thurammia papillata* var. *parallela* var. nov.

Plate XXVII, figs. 14-17.

Test free, elongated and tubular, irregular in section, but generally more or less round, chitinous to finely arenaceous. Papillæ usually most prominent at the extremities. Generally rectilinear, but occasionally curved in outline. Never attaining any great size or coarse investment. The three largest specimens measured were 1.1, 1.03, 1.15 mm. respectively in length, by 0.2, 0.18, 0.2 mm. at point of greatest width.

Arenaceous specimens are easily mistaken at first view for fragments of *Hyperammia* or *Rhabdammina*, but are distinguishable owing to their closed extremities and papillar outgrowths which often form a terminal crown.

Haeusler in 1883 (Ref. 10) figured a number of variations of *T. papillata* which are of great interest, supplemented in 1890 (Ref. 21) by other figures. Figs. 1-4, 10, 25, and 27 of the 1883 paper may be regarded as merely abnormalities of the sphere type, such as are to be found everywhere. Fig. 5, which may be compared with Brady's figure (Ref. 12, fig. 10, pl. xxxvi), and the figures (Ref. 21, figs. 12, 13, 16, 23, 25, 26, pl. vi) (1890), represent a

rare and abnormal form in which all but one or two of the papillæ are suppressed, and these surviving papillæ are abnormally developed, resulting in a shell, flask-shaped, or resembling a broken chamber of a *Reophax* (Pl. XXVII, figs. 18-20). It occurs sparingly in several "Goldseeker" gatherings, but is hardly worth a varietal name. If Gough's specimens from Lough Larne (Ref. 37) are true *Thurammia* they should be referred to this form.

*Thurammia papillata* var. *haeusleri* var. nov.

Types, *T. papillata* Haeusler (Ref. 10, pl. viii, figs. 5-8, 11, 13-24, and Ref. 21, pl. vi, figs. 14, 18).

Plate XXVIII, figs. 1-12; Plate XXIX, fig. 16; Plate XXX, fig. 8.

Nearly all the other figures on the plate of Haeusler's 1883 paper (Ref. 10), and the figs. 14, 18, pl. vi., of his 1890 paper (Ref. 21), represent an amorphous and protean type, which we propose to separate under the varietal name *haeusleri*. No description is possible, because no two specimens ever resemble each other, but in general terms it may be stated that the shell is of irregular form, the papillæ are more strongly developed than in the sphere type, and that the shell texture is subject to the same range of variations, covering every gradation between transparent chitin through fine cement and sand to a coarse arenaceous investment. Chitinous specimens often attain a large size and present a formidable investment of stout spinous papillæ, frequently imperforate. Specimens of var. *haeusleri* are generally more or less compressed, but it is not difficult to obtain a series of specimens linking *haeusleri* through var. *castanea* with the sphere type. We figure a series of specimens representing some of the innumerable variations of this wild-growing form, which is fairly common at several stations.

This appears to be a convenient place in which to deal with certain figures of Brady (Ref. 12). Plate xxxvi, fig. 12, described as "specimen with an internal chamber," represents an irregular sphere type laid open and showing an internal shell of type intermediate between *haeusleri* and the typical sphere. It has attracted a good deal of attention from subsequent writers (Refs. 19, 34, 41), who have found in it support for various theories. The specimen must, however, be regarded as an abnormality. The internal young shell is within the experience covered by the large series of "Goldseeker" specimens always released by the dissolution of the parent shell before the young attain such size or an arenaceous investment.

Brady's figures 13 and 14, pl. xxxvi (Ref. 12), are of greater interest to us, because they are clearly our variety *haeusleri*. They are described as "primordial chambers from other specimens." It is not clear from this whether they were actually removed from

the interior of spheres, or whether Brady identified them as primordial chambers merely on account of their resemblance to the internal shell in fig. 12. If the first alternative is correct, we have definite proof of an alternation of generations between the sphere type and *haeusleri*. The second alternative would merely prove that Brady was acquainted with the variety *haeusleri*, but did not separate it from the sphere type.

Haeusler's remaining species may be quickly dismissed, although we propose to retain the names varietally for taxonomical reasons.

*Thurammia papillata* var. *tuberosa* Haeusler.

Type, Haeusler (Ref. 21, pl. vi, fig. 24, and pl. vii, figs 6-9).

Plate XXVIII, figs. 13-16.

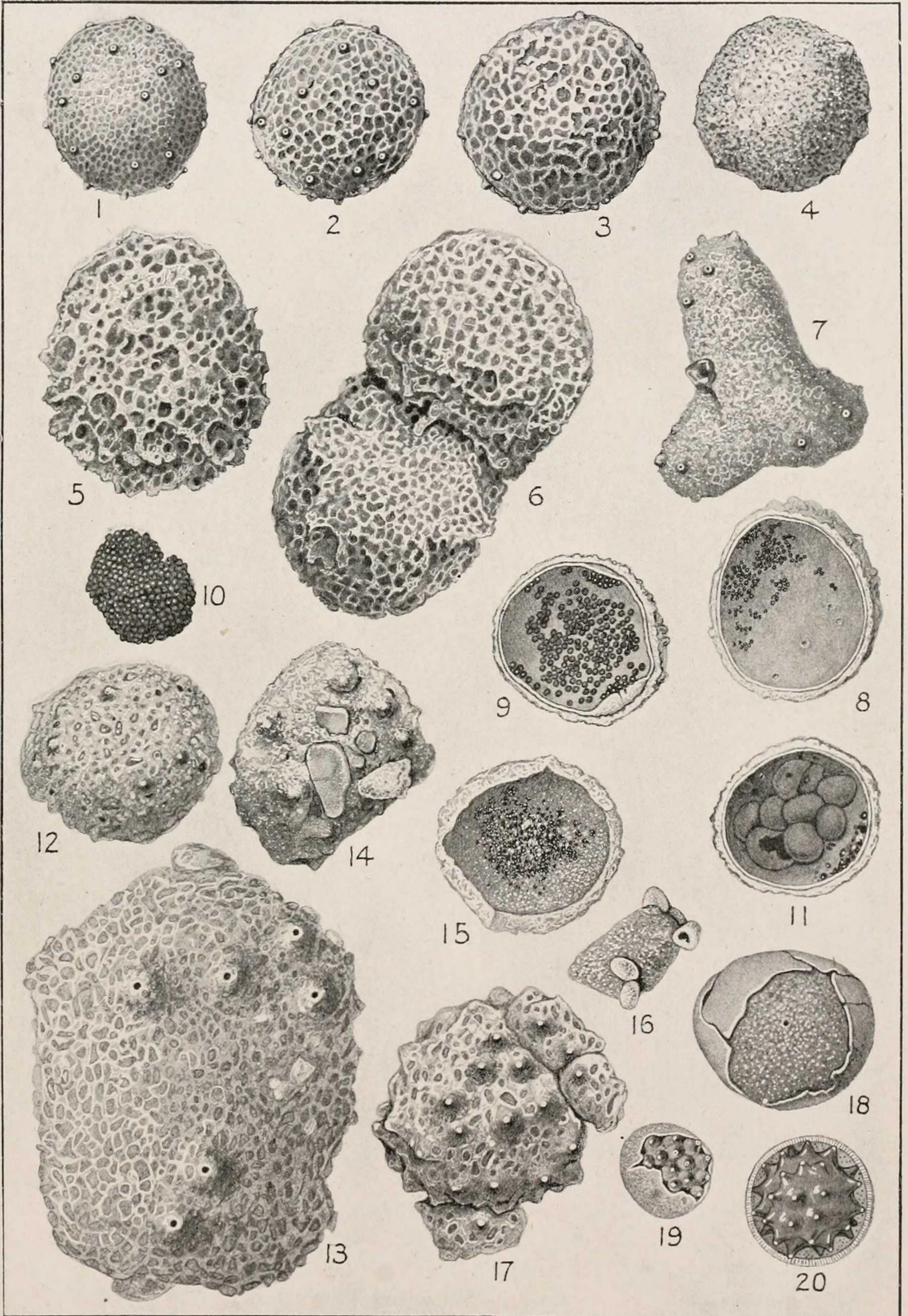
This is merely an aggregation of specimens of an irregular sphere type, and furnished with few papillæ. Such specimens do not attain the size and complication of Haeusler's figures in any of

EXPLANATION OF PLATE XXIX.

FIGS.

- 1-11.—*Thurammia papillata* var. *cariosa* Flint.  
 Figs. 1.—Young sphere, showing commencement of reticulated "cavernous layer" of Flint. (Note: The reticulated markings are somewhat diagrammatized.)  
 „ 2, 3.—Specimens showing development of "cavernous layer" obscuring the papillæ.  
 „ 4.—Specimen with minutely vesiculated "cavernous layer."  
 „ 5.—Specimen with coarsely vesiculated "cavernous layer."  
 „ 6.—Double specimen, with thick "cavernous layer" obscuring the line of junction between the spheres, and eroded in places.  
 „ 7.—Triple specimen, with finely vesiculated "cavernous layer" completely obscuring the junction of the spheres.  
 „ 8.—Internal view of specimen, showing reproductive gemmules lying within the chitinous membrane.  
 „ 9.—The same, gemmules more developed.  
 „ 10.—Aggregation of gemmules removed from test.  
 „ 11.—Internal view, showing spherules at maximum development filling entire cavity.
- 12-15.—*Thurammia papillata* var. *albicans* Brady.  
 Fig. 12.—Typical.  
 „ 13.—Abnormally large and coarsely papillate.  
 „ 14.—Coarsely arenaceous specimen.  
 „ 15.—Section showing grains of magnetite aggregated in central cavity.
- 16.—*Thurammia papillata* var. *haeusleri*. Specimen showing four young individuals (one laid open) budding from parent test.  
 17.—*T. papillata* var. *castanea*. Specimen showing young individuals budding from each side of parent sphere.  
 18.—*T. papillata*. Sphere type, of chitinous cement construction, enclosing a specimen of *Orbulina universa* d'Orbigny, which entirely fills central cavity of the *Thurammia*.  
 19.—*T. papillata*. Sphere type, very finely arenaceous and without papillæ, enclosing var. *castanea*, chitinous form.  
 20.—*T. papillata* var. *castanea*. Chitinous specimen, filling cavity of *Orbulina universa* d'Orbigny.

All specimens magnified 33 diameters.



J. R. Ford, del.

Thurammina.

our gatherings, but the name may be usefully employed for such abnormal individuals as we figure. These are not uncommon in some gatherings.

*Thurammia papillata* var. *elegantissima* Haeusler.

Type, Haeusler (Ref. 21, pl. vii, figs. 12 and 13).

Plate XXX, fig. 11.

Haeusler's type represents a flattened aggregation of small spheres devoid of papillæ. We have so far only observed a few specimens referable to this type, one of which we figure. It may be remarked that Haeusler's two species were described by him as "very rare," so it would seem that these abnormal forms were not more frequent as fossils than they are to-day.

*Thurammia papillata* var. *favosa* Flint.

Type, *T. favosa* Flint (Ref. 30, pl. xxi, fig. 2).

Plate XXVIII, fig. 17.

This variety, characterized by the presence of raised hexagonal meshed walls on the surface of the sphere, would appear to be a very rare variation of the sphere type, there being, so far as we are aware, no records of its discovery, except by Flint, from two Stations in the Gulf of Mexico, in depths of 26 and 420 fms., and by Millett from the Malay Archipelago. It is represented in the "Goldseeker" collections by a few specimens only, including a single chitinous example from Haul 145, Station IX.B, which presents the characteristic honeycomb structure of the surface, and this specimen we figure.

Closely allied to variety *favosa* Flint is a form which occurs rarely in some of the deeper "Goldseeker" dredgings, and for which we propose the varietal name *murata* (*muratus* = enclosed by walls).

*Thurammia papillata* var. *murata* var. nov.

Plate XXVIII, figs. 18-21.

Test free, always of irregular shape, generally compressed, but sometimes roughly spherical, consisting of one (in aggregated specimens two or more) chambers of angular shape, enclosed in walls constructed rather loosely of fine grey sand, the angular edges sharp, generally projecting as walls or flanges, which are more or less spongy or cavernous in structure. Apertures situated along the edges of the flanges, sometimes produced as minute papillæ. Specimens vary somewhat in size. Average diameter about 0.48 mm. Width of the projecting flanges about 0.01 mm.

The whole appearance of the specimens suggests that the test has been constructed in the cavities between sand-grains and pebbles on the bottom, and has taken its shape from its environ-

ment, but no specimens attached to sand grains have been found. The projecting flanges when perfect have the rounded swollen appearance of wet mortar squeezed out between two rows of bricks in building.

*Thurammia papillata* var. *cariosa* Flint.

Type, *T. cariosa* Flint (Ref. 30, pl. xxii, fig. 2).

Plate XXIX, figs. 1-11.

Flint's variety *cariosa* is abundant and typical in "Goldseeker" material, and presents a number of interesting features, which are more readily observed in this form than in its associates, owing to the comparative ease with which it may be sectioned, the spongy test being soft as compared with the other types. We have already referred to the occurrence of young individuals inside the parent.

The "Goldseeker" series of *cariosa* present little variation from Flint's type as described and figured, and the variety is not subject to the wild-growing habits of *papillata*. Beyond the occurrence of compressed individuals, and of double, triple and quadruple specimens, practically no variation exists, except in the extent of the development of the secondary reticulated shell-growth which coats the mature test.

Of the early stages of *cariosa* after the release of the chitinous embryos we have no knowledge. The variety recognizable as such makes its first appearance in all the numerous gatherings, in which we find it as an adult shell of greyish, or sometimes pinkish-grey, colour, constructed of the finest mud or sand, and with a matt surface studded with numerous inconspicuous and almost imperforate papillæ, between which the surface of the sphere is covered with fine reticulated markings (Pl. XXIX, fig. 1). At this stage it is practically indistinguishable from some modifications of the sphere type, except for the faint reticulations. It then begins to coat the surface of the sphere with a layer of spongy shell matter (= "cavernous" layer of Flint), concealing the papillæ and giving the surface of the sphere a dirty and eroded appearance (Pl. XXIX, figs. 2, 3). When two or more individuals are in association this spongy matter often fills up the whole of the intervening gap between the spheres. The size of the cavities in the "cavernous layer" is very variable (Pl. XXIX, figs. 4, 5), and on occasions is so large as to resemble a bath-sponge under a 1-in. objective. The interior of the sphere is smooth and lined with a chitinous film, generally pink to brown in colour. We figure a series of specimens.

*Thurammia papillata* var. *albicans* Brady.

Type, *T. albicans* Brady (Ref. 12, pl. xxxvii, figs. 2-7).

Plate XXIX, figs. 12-15.

Of the recorded species of *Thurammia* only *albicans* Brady remains. This occurs not infrequently in some of the deeper

“Goldseeker” dredgings, where it attains a size considerably greater than Brady records. It appears to be a distinctive form, having little connexion with the typical *papillata*, but in rare instances hardly separable from *cariosa*. The papillæ, when flush with the surface of the test, as they often are, and covered with a loose sandy coat, cannot be distinguished from the outside, but a section will generally reveal a few dimpled pits in the inner wall which mark the position of the superficial papillæ. The papillæ are very few in number, and in some instances perhaps entirely lacking, in which case the form would be indistinguishable from *Storthosphæra*, to which it is possibly nearly allied.

A curious feature observed in connexion with *albicans* is worth recording. The variety appears to have a curious dislike for magnetite. Several specimens which we have laid open contained a number of minute grains of magnetite aggregated in the cavity (Pl. XXIX, fig. 15), the grains having evidently been rejected from the sand collected for the construction of its thick-walled test. This habit may serve to account for the abnormal whiteness of the test of *albicans* as compared with the other varieties. We have observed the same practice in *Storthosphæra*.

*Thurammia papillata* var. *sordida* var. nov.

Plate XXX, figs. 1-6.

We propose this varietal name for a very characteristic form which occurs frequently in several “Goldseeker” gatherings, and which is very distinctive in appearance.

Test free, spherical or irregularly spherical in shape, colour ranging from nearly white to dark brown, slate, or nearly black. Surface rough, and usually coated with finely adherent mud, but specimens have been seen without any muddy layer on the brown chitin sphere. These chitinous specimens have a crinkly surface, and are sometimes covered with very minute papillæ. Interior of the sphere lined with a brown chitinous membrane which is apparently in several layers. The wall of the test appears to consist of a series of chitinous layers alternating with mud incorporated with chitin. No papillæ visible externally as a rule, but papillar depressions are occasionally visible in sectionized tests. The exterior of the sphere is always very wrinkled and dirty in appearance, and frequently has what appears to be sub-chitinous muddy threads, or perhaps dried protoplasmic extrusions, irregularly projecting from it. The colour of var. *sordida* is evidently dependent on the nature of its environment, specimens from Haul 228 (1600 metres, *Globigerina* ooze) being nearly white, and having minute *Globigerinæ* attached to the surface layer of mud, while those from Haul 198 (1236 metres, dark brown mud and sand) are very dark in colour.

The central cavity is generally more or less filled with a dried

mass of brownish protoplasm, which in a few instances shows signs of breaking up into separate particles—perhaps the commencement of the gemmule stage. Associated pairs have been observed, and, as already mentioned, are sometimes linked together by a chitinous investing membrane.

*Size.*—Specimens measured varied between 0.50 and 1.50 mm. in diameter.

*Thurammia papillata* var. *hispida* var. nov.

Plate XXX, fig. 7.

*Thurammia* does not as a general rule present any evidence *pro* or *contra* the vexed question of selective power, although the *sphere* and *haeusleri* forms exhibit great skill in constructing agglutinated tests, using sand-grains of uniform minute size. It is, therefore, of considerable interest to record the occurrence of a few isolated specimens utilizing sponge spicules as a protective coating to the internal sandy sphere in the identical manner adopted by *Crithionina pisum* var. *hispida* Flint. The few specimens observed are all from one locality, Haul 228, 1600 metres.

*Thurammia papillata* var. *canaliculata* (Haeusler).

Type, *Thurammiaopsis canaliculata* Haeusler (Refs. 11 and 21).

Plate XXX, figs. 9, 10.

We have already indicated our doubts as to the sub-generic value of *Thurammiaopsis canaliculata*, and shown how the author of the type appears in his later paper to weaken somewhat in his discrimination between *Thurammiaopsis canaliculata* and the abnormal conglomerations of *Thurammia papillata*. The "Goldseeker" material furnishes no specimens presenting the internal tube structure assigned to *Thurammiaopsis* by Haeusler, but we have many specimens of aberrant *Thurammia* associations

EXPLANATION OF PLATE XXX.

FIGS.

1-6.—*Thurammia papillata* var. *sordida* var. nov.

Fig. 1.—Chitinous sphere collapsed, showing filaments and attached *Globigerinae*.

„ 2.—Sub-chitinous sphere, commencing to incrust.

„ 3.—Incrustation more advanced.

„ 4, 5.—Spheres entirely incrustated.

„ 6.—Sectional view (diagrammatic), to show concentric chitin and mud envelopes.

7.—*T. papillata* var. *hispida* var. nov.

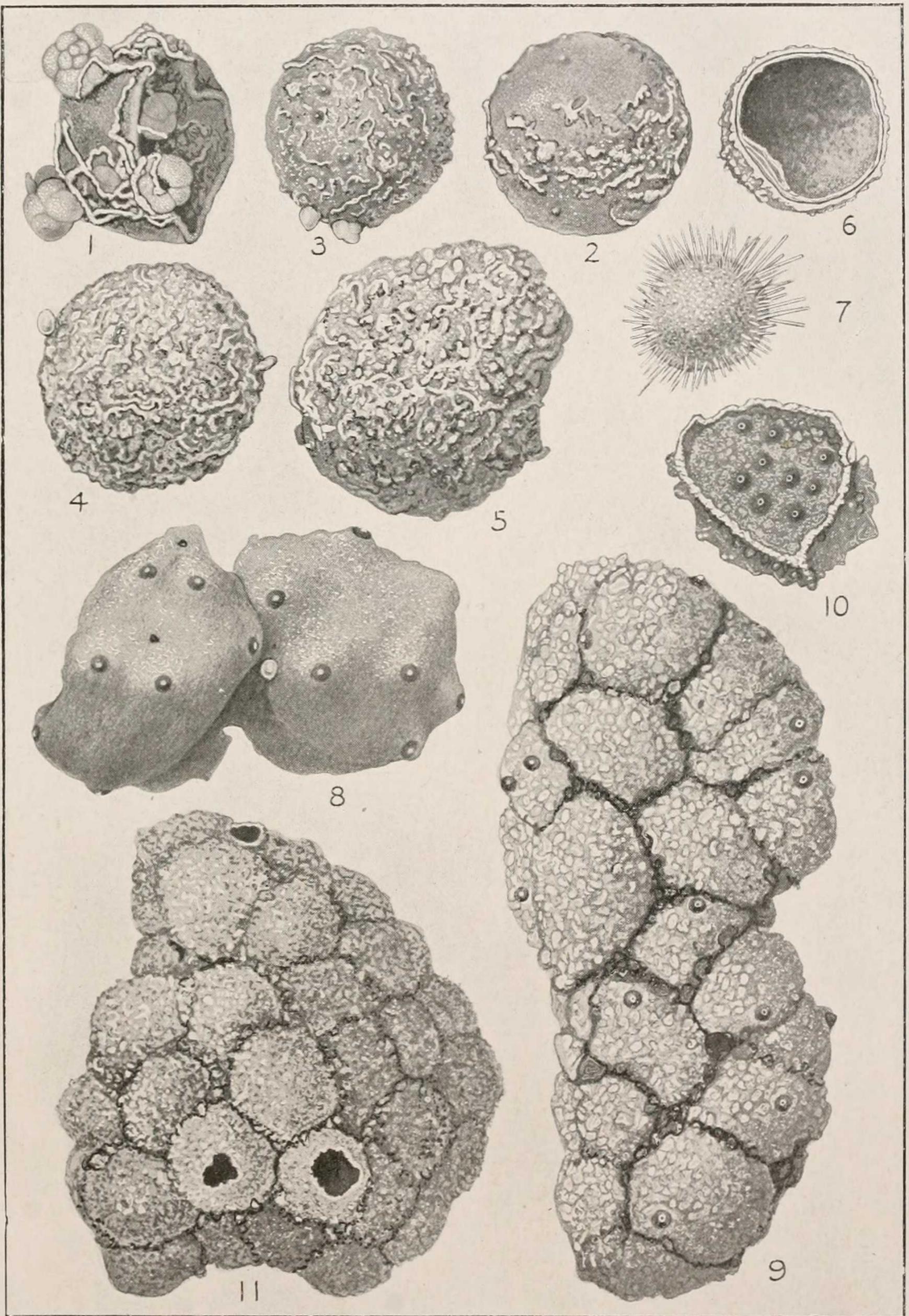
8.—*T. papillata* var. *haeusleri* var. nov. Double specimen.

9.—*T. papillata* var. *canaliculata* Haeusler.

10.—*T. papillata* var. *canaliculata*. Chamber of large specimen laid open, showing internal papillæ, which it is suggested represent the "tubes" of Haeusler.

11.—*T. papillata* var. *elegantissima* Haeusler. A colony of sessile individuals, two being laid open.

All specimens magnified 30 diameters.



J. R. Ford, del.

Thurammina.

presenting external views almost identical with Haeusler's later figures, and, in the absence of his type specimens, we are figuring some under the varietal name *canaliculata*. This is for taxonomical reasons only, as we regard the specimens merely as abnormal growths.

#### SUMMARY OF OBSERVATIONS.

All hitherto recorded species of the genus *Thurammia*, including *Thurammiaopsis canaliculata* Haeusler, are referable to a single specific type, *Thurammia papillata* Brady.

For taxonomical reasons numerous varietal names must be employed, but they have no biological significance.

*Thurammia* commences its existence with a chitinous wall, which is persistent through life, and when an agglutinated shell is formed continues as a lining to the shell.

The wall, whether chitinous or adventitious, is perforate. The perforations may be of the most minute size, or they may take the form of coarse external papillæ.

Among the "Goldseeker" specimens are several which present great biological interest, and raise questions of relationship and development to which there is no present answer.

We figure them for purposes of future reference.

1. *Orbulina* within *T. papillata* of a thin-walled sphere type (Pl. XXIX, fig. 18.). The *Orbulina* is a thick-walled benthic specimen, the *Thurammia* of a semi-chitinous type without visible papillæ or constituent sand-grains. Although the *Thurammia* is, no doubt, more or less flexible, it is difficult to imagine how the *Orbulina*, which fits tightly inside the sphere, could have become accidentally associated with the *Thurammia* through the small fractured opening to be observed. If there is no connexion between the life-history of the two genera—and we have at present no other evidence in support of such a theory—the only explanation possible seems to be the continued development in size of the *Orbulina* after becoming interned as a young individual in the cavity of a broken *Thurammia*.

2. A chitinous *T. papillata* var. *castanea* inside *Orbulina* (Pl. XXIX, fig. 20). We prefer to regard the association as accidental, although the accuracy with which the *Thurammia* fills the entire cavity of the hemisphere, and the chances against such an accidental association, appear remarkable. On any other supposition this specimen must be regarded as the converse of the previously noted abnormality, and would entail belief in an Alternation of Generations between *Orbulina* and *Thurammia*.

3. A chitinous *T. papillata* of a coarsely papillate type (near var. *castanea*), enclosed in and nearly filling the cavity of a sub-chitinous individual of a smooth thin-walled sphere type, devoid of papillæ

(Pl. XXIX, fig. 19). We think there can be no doubt that the internal spinous individual has developed from a spherule secreted by the smooth-shelled parent, and that the specimen may be regarded as proof of the biological identity of these two dissimilar forms, and of the small value to be attached to the development of papillæ. Perhaps, also, as proof of an alternation between these two forms.

## REFERENCES.

1. W. B. CARPENTER. — The Microscope and its Revelations. 5th ed. London, 1875, pp. 533 and 535 (figs. 273 *g*, *h*.).
2. H. B. BRADY. — Reticularian Rhizopoda of the "Challenger" Expedition, pt. 1, 1879. Quart. Journ. Micr. Sci., n.s. vol. xix. pp. 45, 46, pl. v, figs. 4-9.
3. — Ibid., pt. 3 (1881). Quart. Journ. Micr. Sci., n.s. vol. xxi. p. 44.
4. O. BUTSCHLI. — In Bronn's "Klassen und Ordnungen des Thierreiches." 1880-82, vol. i. (1880) p. 202, pl. v, figs. 5 *a-b*.
5. W. B. CARPENTER. — The Microscope and its Revelations. 6th ed., 1881, p. 563 (figs. 320 *g*, *h*.).
6. V. UHLIG. — Ueber einige ober-jurassische Foraminiferen mit agglutinierende Schalen. N. Jahrb. f. Min., etc. (Jahrg. 1882) vol. i. p. 152.
7. R. HÆUSLER. — Notes sur les Foraminifères de la zone à Ammonites transversarius du Canton d'Argovie. Bull. Soc. Vaud. Sci. Nat., 1882, vol. xviii. 88, p. 226.
8. — Notes on some Upper Jurassic Astrorhizidæ and Lituolidæ. Quart. Journ. Geol. Soc., vol. xxxix. (1883) p. 27.
9. — Die Astrorhiziden und Lituoliden der Bimammatus-zone. N. Jahrb. f. Min., etc. (Jahrg. 1883) vol. i. p. 60, pl. iv, figs. 9-14.
10. — On the Jurassic varieties of *Thurammia papillata* Brady. Ann. Mag. Nat. Hist., ser. 5, vol. xi. pp. 262-6, pl. viii.
11. — Ueber die neue Foraminiferen-gattung *Thuramminopsis*. N. Jahrb. f. Min., etc. (Jahrg. 1883) vol. ii. p. 68.
12. H. B. BRADY. — Report on the Scientific Results of the Voyage of H.M.S. "Challenger" (Zoology) vol. ix. Report on the Foraminifera, 2 vols. (text and plates) London, 1884, pp. 321-4, pl. xxxvi, figs. 7-18, and pl. xxxvii, figs. 1-7.
13. R. HÆUSLER. — Die Lituoliden-fauna der Aargauischen Impressaschichten. N. Jahrb. f. Min., etc., Appendix vol. iv. 1885, p. 30, pl. iii, fig. 35.
14. J. WRIGHT. — Cretaceous Foraminifera of Keady Hill, Co. Derry. Proc. Belfast Nat. Field Club, 1886. Appendix, 1884-6, p. 329, pl. xxvii, fig. 12.
15. H. B. BRADY. — Synopsis of the British Recent Foraminifera. Journ. R. Micr. Soc., 1887, p. 891.
16. R. HÆUSLER. — Notes on some Foraminifera from the Hauraki Gulf. Trans. N.Z. Institute, vol. xix. 1887 (Wellington, N.Z.).
17. A. AGASSIZ. — Three Cruises of the "Blake." 1888, vol. ii. p. 164, fig. 496.
18. C. D. SHERBORN & F. CHAPMAN. — Additional Note on the Foraminifera of the London Clay. Journ. R. Micr. Soc., 1889, p. 484, pl. xi, fig. 9.
19. F. DREYER. — Die Pylombildungen in vergleichend-anatomischer und entwicklungsgeschichtlichen Beziehung bei Radiolarien und bei Protisten überhaupt. Jena. Zeitschr. f. Naturw., vol. xxiii. N.F. xvi (1889) p. 111, pl. vi, fig. 94.
20. — Betrachtungen über den Bau der Rhizopodenschalen. Biol. Centralbl., vol. ix. (1889) p. 341.

21. R. HÆUSLER.—Monographie der Foraminiferen-fauna der Schweizerischen Transversarius-zone. Abh. Schweiz. Pal. Ges., vol. xvii. (1890) pp. 46 *et seq.*, pls. vi–viii.
22. J. WRIGHT.—Report on the Foraminifera of the South-west of Ireland. Proc. R. Irish Acad., ser. 3, vol. i. (1891) No. 4, p. 468.
23. F. CHAPMAN.—Foraminifera of the Gault of Folkestone. Journ. R. Micr. Soc., 1892, p. 325, pl. vi, fig. 9.
24. R. HÆUSLER.—Notes sur la distribution des Lituolides dans les Terrains Jurassiques de le Suisse. Mem. Soc. Pal. Suisse, Geneva, vol. xix. (1892) Geneva, 1893, pp. 38, 39.
25. J. G. EGGER.—Foraminiferen aus Meeresgrundproben . . . von S. M. Sch. Gazelle. Abh. d.k. bayer. Akad. d. Wiss., Kl. II. vol. xviii. pt. 2 (Munich, 1893) p. 71, pl. v, fig. 9.
26. W. HOWCHIN.—A Census of the Fossil Foraminifera of Australia. Austr. Assoc. Adv. Sci., 1893, p. 16. (Reprint.)
27. A. GOËS.—Foraminifera of the West Coast of Central America: U.S. Steamer "Albatross." Bull. Mus. Comp. Zool. Harvard, vol. xxix. No. 1, pp. 25, 26, pl. ii, figs. 9, 10.
28. G. H. T. EIMER & C. FICKERT.—Die Artbildung und Verwandtschaft bei den Foraminiferen. Tübinger Zool. Arbeiten, vol. iii. (1899) No. 6, p. 600.
29. J. G. EGGER.—Foraminiferen und Ostracoden aus den Kreidemergeln, der Ober-bayerischen Alpen. Abh. k. bayer. Akad. Wiss. Kl. II. vol. xxi. (1899) pt. 1, p. 15, pl. ii, figs. 14–16, and p. 176, pl. xxv, figs. 51–3.
30. J. M. FLINT.—Recent Foraminifera . . . dredged by the U.S. Steamer "Albatross." Rep. U.S. Nat. Mus., 1897 (Washington, D.C., 1899).
31. W. B. CARPENTER.—The Microscope and its Revelations. 8th ed. 1901, p. 815, figs. 614 *g, h*.
32. F. CHAPMAN.—The Foraminifera. London, 1902, p. 148, pl. viii, fig. A.
33. L. RHUMBLER.—Systematische Zusammenstellung der recenten Reticulosa. Arch. f. Protistenk., vol. iii. (1903) pp. 236–7, figs. 65–70.
34. A. KEMNA.—Morphologie des Foraminifères arénacés. Ann. Soc. Roy. Zool. et Malac. Belgique, vol. xxxix. (1904) p. 31.
35. F. W. MILLETT.—Report on the Recent Foraminifera of the Malay Archipelago. Journ. R. Micr. Soc., 1904, p. 608, pl. xi, fig. 7.
36. F. CHAPMAN & W. HOWCHIN.—A Monograph of the Foraminifera of the Permo-Carboniferous Limestones of New South Wales. Mem. Geol. Surv. N.S.W., 1905 (Palæontology) No. 14, p. 9, pl. ii, fig. 13.
37. G. C. GOUGH.—The Foraminifera of Larne Lough District. Fisheries, Ireland, Sci. Invest., 1905, iii. (1906) p. 4, pl. i, fig. 9.
38. J. A. CUSHMAN.—Monograph of the Foraminifera of the North Pacific Ocean, pt. 1, 1910. Smithsonian Inst., Bull. No. 71, pp. 57–9, figs. 66–72.
39. E. HERON-ALLEN & A. EARLAND.—The Foraminifera of the Clare Ireland District, Co. Mayo, Ireland. Proc. Roy. Irish Acad., vol. xxxi. (1913) pt. 64, p. 47, pl. lxiv.
40. J. A. CUSHMAN.—New Textularidæ and other Arenaceous Foraminifera from the Philippine Islands and contiguous waters. Proc. U.S. Nat. Mus., vol. xlv. (1913) p. 637, pl. lxxix, fig. 4.
41. L. RHUMBLER.—Die Foraminiferen (Thalamoporen) der Plankton Expedition, pt. 2. Kiel and Leipzig: 1913, p. 361, text-fig. (after Brady) cxviii.
42. E. HERON-ALLEN & A. EARLAND.—The Foraminifera of the Kerimba Archipelago, Portuguese East Africa. Trans. Zool. Soc. Lond., vol. xx. (1915) p. 617.
43. ——— The Foraminifera of the West Coast of Scotland. Trans. Linn. Soc., vol. xi. (ser. 2, Zoology) 1916, pt. 13, p. 225.

## Thurammia

No.	No. of Haul	Station	Locality	Depth in Metres	Nature of Deposit	Typical Sphere = "Orbuline <i>Lituola</i> " of Carpenter				
						Chitin	Cement	Grey micaceous	Black	Type
1	8215	viii	61° 30' N. 3° 3' E.	375	m. s.	×		×	×	×
2	various	ix	61° 34' N. 2° 4' E.	333-370	m. s.	×	×	×	×	×
3	145	ix B	A few miles E. of station ix	330	m. s.	×	×	×	×	×
4	228	..	57° 59' N. 10° 34' W.	1600	gl. ooze	×		×	×	×
5	224	..	58° 43' N. 8° W. ..	448	sand from Spatangus stomachs	×				
6	225	..	58° 43' N. 9° 6' W.	1448	gl. o.	×				
7	129	..	59° 25' N. 7° 4' W.	1140	gl. o.					×
8	8149	..	59° 25' N. 7° 33' W.	1100	s. gl. o.					×
9	36	liii	59° 36' N. 7° W. ..	1000	s. gl. o.	×		×		×
10	123	..	59° 41' N. 8° W. ..	850	gl. o.					
11	121	..	60° 6' N. 6° 31' W.	1063	gl. o. s. st.	×				×
12	95	xix B	60° 23' N. 4° 6' W.	525	c. s. sh.					
13	119	..	60° 34' N. 4° 32' W.	965	s. gl. o.	×				×
14	53	xix A	60° 36' N. 4° 46' W.	1078	gr. m.					
15	218	xviii A	60° 57' N. 5° 47' W.	330	gr. m.	×				
16	221	xiv A	61° 18' N. 2° 59' W.	1278	m. s. st.	×		×		×
17	172	xv A	61° 27' N. 3° 42' W.	1280	m. s.	×				×
18	199	..	61° 31' N. 2° 20' W.	1418	s. o.	×				×
19	?	xv B	61° 39' N. 4° 45' W.	253	m. s. sh.	×				×
20	198	xi A	61° 42' N. 2° W. ..	1236	c. s. o.	×		×		×
21	88	xvi A	61° 49' N. 5° 36' W.	205	s. sh.					×

m = mud

sh = shell

st = stones

gl = globigerina

*papillata* BRADY.

var. <i>castanea</i> H.-A. & E.	var. <i>compressa</i> Brady	var. <i>parallela</i> H.-A. & E.	var. <i>haeusleri</i> H.-A. & E.	var. <i>tuberosa</i> Haeusler	var. <i>elegantissima</i> Haeusler	var. <i>favosa</i> Flint	var. <i>murata</i> H.-A. & E.	var. <i>cariosa</i> Flint	var. <i>albicans</i> Brady	var. <i>sordida</i> H.-A. & E.	var. <i>hispida</i> H.-A. & E.	var. <i>canaliculata</i> Haeusler	Remarks
x	x	x	x			x		x		x			
x	x	x	x			x		x		x		?	Chitinous and cement forms predominate
x	x	x	x			x		x	x	x	x		All very rare
x	x	x	x			x		x	x	x			All very rare
x	x	x	x			x		x	x	x			All very rare
x	x	x	x			x		x	x	x			Only a few specimens
x	x	x	x			x		x	x	x			<i>cariosa</i> frequent, others very rare
x	x	x	x	x		x		x	x	x			Only one seen
x	x	x	x			x		x	x	x			Very rare
x	x	x	x			x		x	x	x			? One doubtful specimen seen
x	x	x	x			x		x	x	x			All rare
x	x	x	x			x		x	x	x			Very rare
x	x	x	x			x		x	x	x			? All very rare
x	x	x	x		x	x		x	x	x			Type and frequent, <i>castanea</i> others very rare
x	x	x	x			x		x	x	x			? All rare
x	x	x	x			x		x	x	x			? All rare
x	x	x	x		x	x		x	x	x			<i>sordida</i> and <i>albicans</i> frequent, <i>castanea</i> very fine
x	x	x	x	x		x		x	x	x			? The best station for the specimens referred to as var. <i>canaliculata</i>

s = sand      gr = gravel      o = ooze      c = coarse      f = fine

# Journal of the Royal Microscopical Society

CONTAINING ITS TRANSACTIONS AND PROCEEDINGS

AND

A SUMMARY OF CURRENT RESEARCHES RELATING TO  
**ZOOLOGY AND BOTANY**  
(principally Invertebrata and Cryptogamia)  
**MICROSCOPY, &c.**

EDITED BY

**R. G. HEBB, M.A. M.D. F.R.C.P.**

WITH THE ASSISTANCE OF THE PUBLICATION COMMITTEE AND

**J. ARTHUR THOMSON, M.A. LL.D.**  
*Regius Professor of Natural History in the  
University of Aberdeen*

**A. N. DISNEY, M.A. B.Sc.**

FELLOWS OF THE SOCIETY

AND

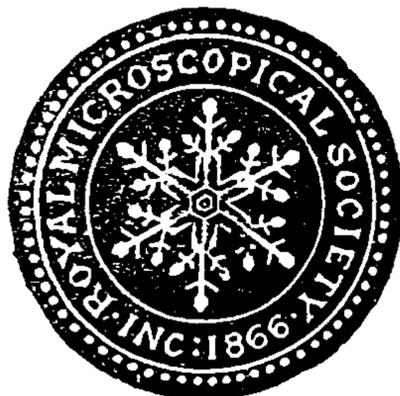
**A. B. RENDLE, M.A. D.Sc. F.R.S. F.L.S.**  
*Keeper, Department of Botany, British Museum*

**R. M. JONES, M.Sc.**  
*Woolwich Arsenal*

**RALPH ST. JOHN BROOKS,**  
M.A. M.D. D.P.H. D.T.M. & H. (CAMB.)

Minimis partibus, per totum Naturæ campum, certitudo omnis innitur  
quas qui fugit pariter Naturam fugit.—*Linnaeus.*

FOR THE YEAR  
1917



TO BE OBTAINED AT THE SOCIETY'S ROOMS  
20 HANOVER SQUARE, LONDON, W.  
OF MESSRS. WILLIAMS & NORGATE, 14 HENRIETTA STREET, LONDON, W.C.  
AND OF MESSRS. DULAU & CO., 37 SOHO SQUARE, LONDON, W.