

4. *On the RADIOLARIA in the DEVONIAN ROCKS of NEW SOUTH WALES.*
By GEORGE JENNINGS HINDE, Ph.D., F.R.S., F.G.S. (Read
November 9th, 1898.)

[PLATES VIII & IX.]

CONTENTS.

	Page
I. Introduction	38
II. Character of the Rocks and Mode of Preservation of the Radiolaria.	38
(a) The Chert-rocks with Radiolaria.	
(b) The Siliceous Limestones with Radiolaria.	
(c) The Siliceous Claystones and Shales with Radiolaria.	
(d) The Volcanic Tuffs with Radiolaria.	
III. Description of the Radiolaria	42
IV. General Characters and Affinities of the Radiolaria	58
V. Fossils associated with the Radiolaria	60
VI. Summary	61

I. INTRODUCTION.

ON the invitation of the authors of the foregoing paper, I very willingly consented to undertake an examination and description of the radiolaria occurring in the extensive series of Devonian rocks in New South Wales which they have recently brought to light, and accordingly they forwarded to me, in the spring of 1897, a box of hand-specimens of typical examples of the different kinds of radiolarian rocks, and these have been supplemented since by a few other specimens received during the present year. Microscopic sections have been prepared from them; and from such as contained the radiolaria in good preservation (as, for example, the dark siliceous limestones and some of the volcanic tuffs from Tamworth), numerous slides were made, so as to obtain as large a variety of the organisms as possible.

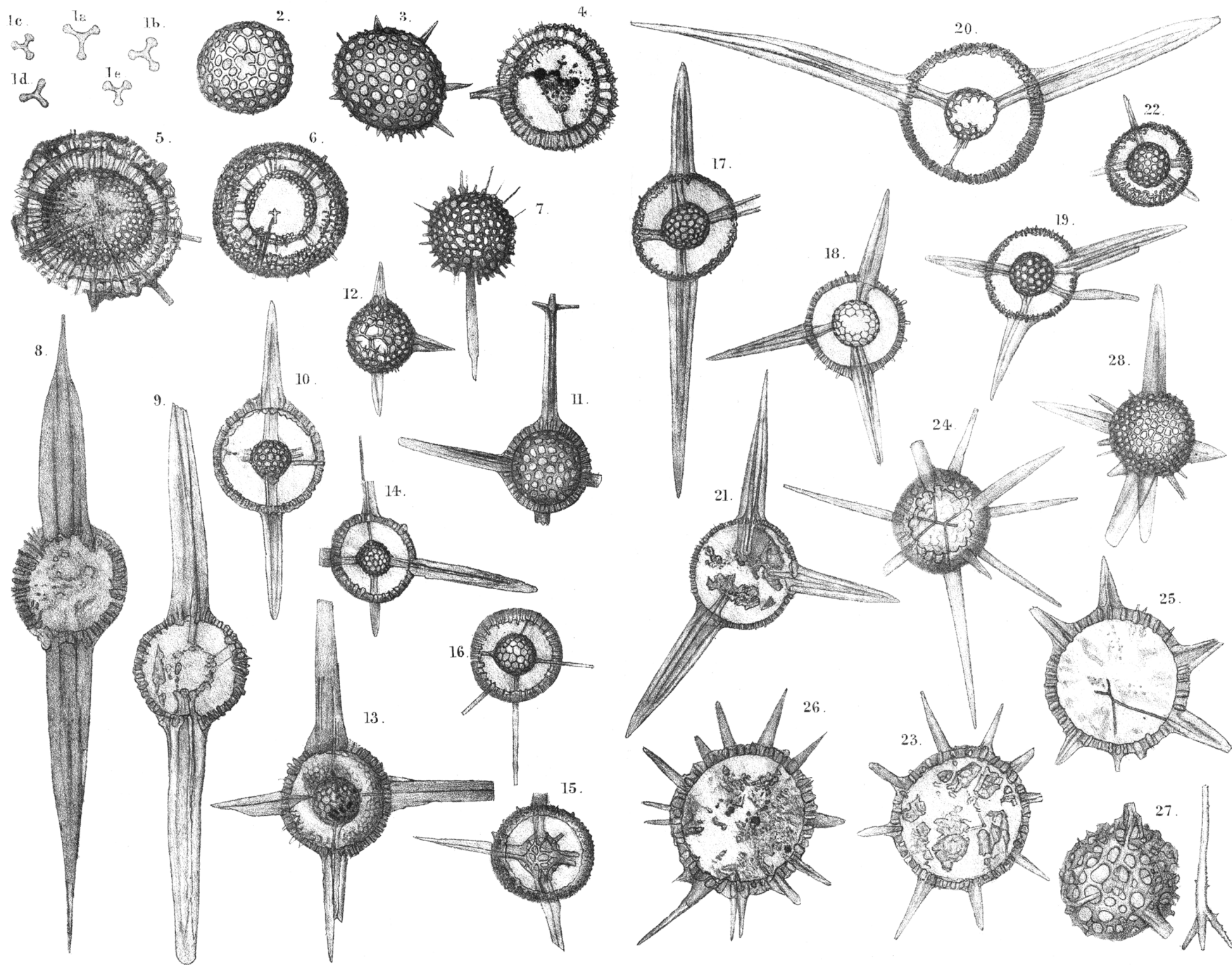
The rocks sent me were derived from the following four localities:—(1) Bingara and (2) Barraba: red jaspery cherts; (3) Jenolan Caves and vicinity: black chert; (4) Tamworth: black chert, dark siliceous limestone, siliceous claystone or shale, and volcanic tuff.

II. CHARACTER OF THE ROCKS AND MODE OF PRESERVATION OF
THE RADIOLARIA.

Before describing the radiolaria, it will be desirable to refer to the character of the rocks of which they form so important a part, and to their mode and condition of preservation.

(a) The Chert-rocks with Radiolaria.

The jaspery cherts of Bingara and Barraba are hard and flinty, of a brick-red tint, and fairly translucent in section. They are traversed in all directions by thin microscopic veins and strings of microcrystalline quartz. The rock is cryptocrystalline; only a few

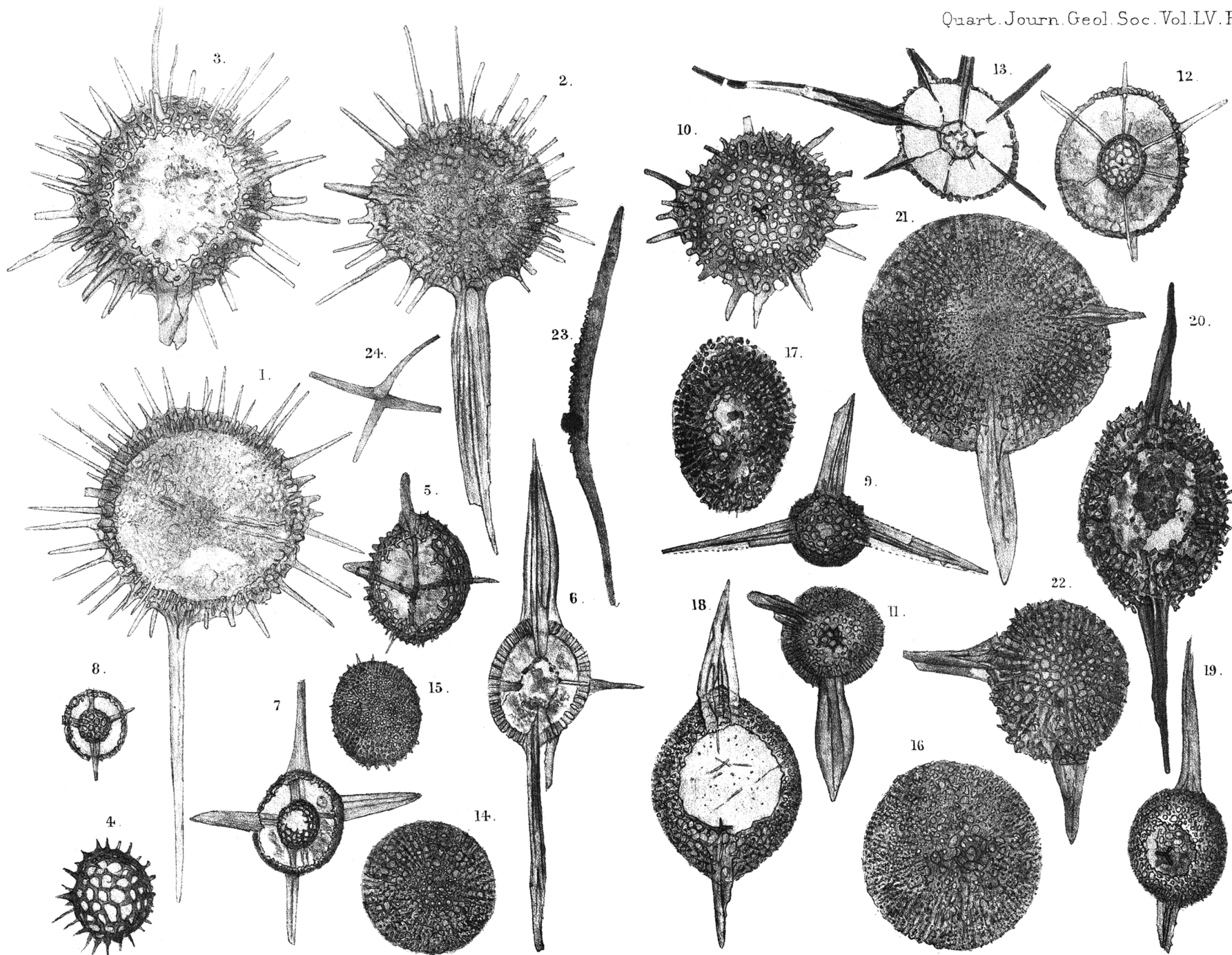


A.T. Hollick del. et lith.

RADIOLARIA FROM THE DEVONIAN ROCKS OF NEW SOUTH WALES.

All $\times 200$ diameters.

Mintern Bros. imp.



casts of radiolaria can be distinguished in it; these are extremely shadowy and indistinct, and can scarcely be differentiated from the groundmass. I can see no evidence of metamorphism in the rock; it closely resembles some jaspers radiolarian cherts from the Culm of Devon, and also some, of presumed Jurassic age, from California, in which there is no question of contact-alteration. The samples examined were:—No. 575,¹ from Lower Bingara, and No. 573, from Oakey Creek.

In only one of the chert-specimens from the Jenolan Cave district (No. 569, McKeown's Creek) have I been able to recognize radiolaria. This rock is a black chert traversed by a close network of microscopic quartz-veins. The radiolaria are fairly abundant; they are in the condition of casts of microcrystalline silica, without structure, and neither spines nor central tests are shown. The rock is a radiolarian chert without indications of metamorphism.

The other specimens (Nos. 568, 570) from the same locality as the above are black, opaque, impure cherts, in which no organisms could be seen, and the same may be said of a specimen from Cave Creek (No. 571) in which there is an admixture of fragments of tuff.

At Tamworth the chert associated with the dark siliceous limestones is a hard, black, compact rock, very finely laminated, as shown by lines of lighter and darker materials in the microscopic sections. The matrix is filled with dark, minutely granular, or flocculent material, considered as carbonaceous by Messrs. David & Pittman; but some of it may possibly be ferruginous. This dark substance is either generally dispersed throughout the rock, or occurs in denser patches and streaks. In thin section under the microscope the rock is seen to be crowded with radiolaria, which appear as small, clear spots, for the most part circular in outline, without definite bounding-walls. Neither spines nor central tests are shown in the great majority of the forms. The radiolarian casts are usually infilled with cryptocrystalline silica, sometimes with fibrous chalcedonic silica, and in exceptional instances with crystalline quartz.

The radiolaria preserved in this dark chert are distinguished from those in the intervening beds of dark siliceous limestone by the absence of the latticed structure of the cortical test, and the nearly complete disappearance of the radial spines and medullary test. It can hardly be doubted that the chert forms were originally of a similar character to those in the limestone interbedded with the chert, and that their present differences arise from the different conditions of fossilization in the chert and limestone respectively. Judging only from their present appearance, the simple, spineless forms in the chert would be referred to groups quite distinct from those in the dark limestone, with which, there is good reason to believe, they were originally identical.

In one specimen from Tamworth (No. 375, 4-5) a nodule of the black chert is enclosed in a bed of tuff. The chert appears to be

¹ The numbers affixed to the specimens throughout this paper are those used by Messrs. David & Pittman.

but very slightly, if at all, altered; the casts of radiolaria are similar to those in the chert described above, and the groundmass has less of the dark carbonaceous(?) material and a somewhat larger number of very minute polarizing particles.

In general characters the radiolarian chert from these Australian localities very closely resembles that from Mesozoic and Palæozoic formations in other parts of the world. The radiolaria in it are too poorly preserved for either generic or specific determination; one can only say that the rock is filled with their casts, and that the silica of the chert has most probably been derived from their tests.

(b) The Siliceous Limestones with Radiolaria.

The examples of this rock which I have examined are all from Tamworth, and they bear the following numbers:—245 3, 247 3-4, 248 4, 256 3, 4-4 a. The rocks are dark to a dull black, fine-grained, compact, homogeneous. They weather on the outer surface to a porous brown crust, having much the appearance of rottenstone. In only one instance (248 4) is the rock traversed by minute veins, and these are partly filled with calcite and partly with microcrystalline silica. The rock readily effervesces in acid, and leaves a brown residue in which there may be seen fairly perfect radiolaria in whitish silica, with spines and central tests. Rarely, however, are the organisms completely freed from the porous brown matrix, and they are altogether too fragile to be manipulated for examination, so that for this recourse must be had to microscopic sections.

In thin microscopic sections of this dark limestone, made in the usual manner, the radiolaria are very imperfectly shown; as a rule, only the outlines of circular and oval forms, without spines, are visible, and the tests and the interspaces of the groundmass are filled with somewhat dirty-looking calcite. On removing, however, the calcite by etching the thin section in position on the glass slide with dilute acetic acid for a short time, and after gently washing it and covering it cautiously with balsam and thin glass, the radiolaria are shown with remarkable distinctness. In many of the tests, which range between 0.06 and 0.2 mm. in diameter, the radial spines and the inner or medullary tests are perfectly preserved; in these latter, as a rule, the delicate latticed structures are shown more clearly than in the outer or cortical tests. The tests and spines are, not infrequently, as transparent as in recent or Tertiary forms, and, like these, they retain the original amorphous condition of the silica. But more generally the original tests are now replaced by a dark substance, as if some compound of iron had united with the silica. Also many of the radiolaria are now represented only by hollow casts, their tests having been dissolved.

In the best preserved of the etched sections, the rock—*minus* the calcite—appears to be wholly composed of the tests of radiolaria, crowded together and embedded in a confused mass of broken spines and fragments of lattice-work, the débris of forms which have gone

to pieces when the radiolaria were being deposited at the sea-bottom.

In polarized light between crossed nicols, the etched sections for the most part remain dark, but occasionally the faint outlines of radiolaria in cryptocrystalline silica are visible, and also minute polarizing particles of uncertain character. Microscopic cubes of pyrites are not at all uncommon in the dark limestones, but I have not observed any elastic inorganic fragments.

The calcareous constituent of this radiolarian siliceous limestone appears to be wholly in the form of crystalline calcite, and there are no indications in the specimens examined of foraminifera or other calcareous organisms which could have furnished the calcite. It is possible that originally they may have been in the rock and subsequently obliterated, for in the coral-limestones which occur in part of the Tamworth series (258 B) the coral-structure is now replaced by calcite. However this may be, it seems clear that this siliceous limestone must have been originally a radiolarian ooze, and that the calcite which now infills the tests and interspaces of the organisms was subsequently introduced, giving solidity and density to the light, porous, siliceous aggregate. The rock when treated with acid remains of the same volume after the lime has been removed, and the porous residue, as we have seen, essentially consists of the siliceous remains of radiolaria.

From the etched sections of this rock about half the forms described and figured in the following pages were obtained.

(c) The Siliceous Claystones and Shales with Radiolaria.

The only specimens of this description of radiolarian rock that I have examined are from Tamworth (590, 625 25), where Messrs. David & Pittman¹ have ascertained that it is some thousands of feet in thickness. The rock is greyish-brown, somewhat lighter-tinted on the outer surface, compact, jointed, and traversed in places by narrow quartz-veins. It gives no reaction in acid. The weathered surface of the rock is covered with minute grey specks, barely visible to the naked eye; these with a lens are seen to be radiolaria, partially weathered out from the brownish matrix. In some instances the lattice-structure, and more frequently the radial spines of the organisms are preserved in position. A thin section of the rock under the microscope shows a translucent ground-mass of very minute, brownish, polarizing particles. The rock is crowded with radiolaria, which, however, in the section show neither structure nor spines; they are now infilled with a brownish material (whitish-grey by reflected light) of an uncertain character.

As the authors of the foregoing paper remark, this claystone and shale apparently contain as many radiolaria as the black chert, while the chemical analysis shows a distinctly smaller proportion of

¹ These authors state that the claystones at Bingara and Barraba are lithologically similar to those exposed at Tamworth.

silica in the rock. This seems to be accounted for by the greater quantity of very fine clay or silicate of alumina that has taken the place of the silica. The radiolaria in the rock, judging from the weathered-out forms, are fairly well preserved, but in the microscopic sections they are obscured by the aluminous groundmass, which cannot be eliminated as in the case of the calcium carbonate in the siliceous limestones. Hence their generic and specific characters cannot be determined with precision, but there is no reason to doubt their similarity to the forms in the intervening siliceous limestones.

(d) The Volcanic Tuffs with Radiolaria.

Some of the beds at Tamworth associated with the radiolarian siliceous limestones and claystones appear to be made up mainly of volcanic detritus, judging from the characters shown in microscopic sections. The specimens examined bear the numbers 240 A 1, 243 2, 249 A 1, 257 A, 380 D-E, and 387 D. The rocks are mostly of a bluish tint; they may be scratched with a penknife, and readily effervesce in acid. The outer surface weathers to a rusty brownish crust of fine and coarse granular materials. Under the microscope the rock is seen to consist of irregular fragments of tuff, lapilli, and ash of different degrees of fineness; in a coarse example the fragments range up to 2.5 mm. in diameter. Some fragments are vesicular, and the vesicles are regularly oval and often filled with a greenish mineral. As they are of about the same size as radiolarian casts, they might easily be mistaken for these organisms. The base or groundmass of the tuff-rock is calcite, which cements the fragments together. Scattered sparsely between the tuff-fragments and, like them, embedded in the calcitic base there are a few radiolaria, which can hardly be seen until the calcite has been removed by acid, in the same way as in the radiolarian limestones. The forms in the tuff-rocks are generally well preserved; the lattice-structure of the outer and inner tests and the radial spines can be distinguished, and they still retain the colloid silica of the test. In exceptional instances the interior of the test has been infilled with colloid silica, but more usually with calcite. Owing to their isolated occurrence, the systematic characters of these tuff radiolaria can be better ascertained than in the forms in the limestones, and a majority of those described and figured in the following pages are from a single hand-specimen of tuff (387 D), in which the fragments are coarser than the average.

III. DESCRIPTION OF THE RADIOLARIA.

The descriptions and figures which follow have in all cases been taken from the radiolaria seen by transmitted light, in the etched microscopic sections of the dark siliceous limestones and the volcanic tuffs of the Tamworth series. It has not been found practicable to figure the forms weathered out on the surface of the rocks, or partially set free by acid. In the etched sections the outer cortical

tests of the radiolaria are less frequently shown than the inner or medullary tests. The forms in the tuff are best preserved; those in the limestones are usually so thickly mingled together that their characters are often hidden, while the chert forms, being casts merely without structure, are of no use for systematic description. The classification of Haeckel, as given in his *Challenger Report on the Radiolaria*,¹ has been followed.

The measurements given are in millimetres and decimal parts, and the figures in the plates are all drawn to the same scale of 200 diameters. As the radiolaria are all from Tamworth and belong to the same series of Devonian rocks, the locality and formation are not repeated with each species, and only the numbers of the beds are given. The slides containing the figured specimens are in my own collection.

Class **RADIOLARIA**, Müller.

Subclass *SPUMELLARIA*, Ehrenberg.

Order **BELOIDEA**, Haeckel.

Genus *SPHEROZOOM*, Meyen.

The skeleton consists of free siliceous spicular bodies of various forms.

SPHEROZOOM sp. (Pl. VIII, figs. 1 *a*–1 *e*.)

The only spicules of this genus which have been observed are very minute, apparently three-rayed forms; the rays are short and have either rounded or truncate terminations, or they are club-shaped. They range between 0.03 and 0.04 mm. in diameter. They have the same glistening appearance as that already noticed in these spicules from other deposits. They occur detached and very sparingly, both in the dark siliceous limestones and in the volcanic tuffs. Nos. 4, 245 *z*, 387 *D*. Similar forms have been found in nearly all radiolarian rocks from the Cretaceous downwards.

Order **SPHÆROIDEA**, Haeckel.

Genus *CENOSPHERA*, Ehrenberg.

The test is a simple latticed sphere, without radial spines.

CENOSPHERA SCITULA, sp. nov. (Pl. VIII, fig. 2.)

Test small, with delicate narrow lattice-bars; the pores are somewhat subangular and unequal; in the angles are very minute spines. Diameter of test, 0.09 mm.; of the pores, 0.01 mm. Rare. In siliceous limestone. No. 245 *z*. This form corresponds in size with *C. minuta*, Pantanelli, but according to Dr. Riist² the pores in this latter are only about half the size of those in *C. scitula*.

¹ Zoology, vol. xviii (1887).

² Palæontographica, vol. xxxiv (1888) p. 190.

CENOSPHERA AFFINIS, sp. nov. (Pl. VIII, fig. 3.)

This form corresponds in size with the preceding, but the pores are more regular and nearly circular, and the surface-spines are more prominent. Diameter of test, 0.1 to 0.13 mm.; of the pores, 0.015 mm.; length of spines, 0.03 mm. In the siliceous limestones and in the volcanic tuff. Nos. 245 α , 387 β .

Genus *LIOSPHERA*, Haeckel.

The test consists of two concentric latticed spheres, both extra-capsular.

LIOSPHERA (?) sp. ind. (Pl. VIII, fig. 4.)

The specimen is only shown in section, and the pores are not distinguishable; the inner sphere is connected with the outer by numerous rods, which extend as small spines beyond the surface of the outer test. The lower portion of a stouter spine is also present. Diameter of the outer sphere, 0.145 mm.; of the inner, 0.09 mm. Rare. In siliceous limestone. No. 245 β .

Genus *RHODOSPHERA*, Haeckel.

The test is composed of three concentric spheres, one medullary and two cortical.

RHODOSPHERA RUESTI, sp. nov. (Pl. VIII, fig. 5.)

The cortical tests are only shown in section, and the outer one is but imperfectly preserved. Numerous rods or spokes connect the medullary with the cortical spheres, and some of these are extended into short spines. The medullary test has nearly circular pores, and there are indications of rods radiating from its centre. Diameter of outer test, 0.155 mm.; of the inner cortical, 0.13 mm.; and of the medullary, 0.1 mm. Rare. Found in dark siliceous limestone. No. 245 γ . The species is named in honour of Dr. H. Rüst, of Hanover.

Genus *SPONGOPLEGMA*, Haeckel.

An outer cortical sphere of spongy framework, enclosing in the centre a single latticed sphere.

SPONGOPLEGMA AUSTRALE, sp. nov. (Pl. VIII, fig. 6.)

The cortical test consists of a minutely porous mesh, and the exterior surface is somewhat rough. The medullary test is smooth, delicate, and with minute, somewhat subangular, pores; it is connected with the porous test by numerous slender rods. Within the medullary test there are several very small, free, spicular bodies, having three or four rays, not unlike *Sphaerozoum*-spicules, but of a more slender character. Diameter, 0.12 mm.; thickness of spongy sphere, 0.02 mm.; diameter of the medullary test, 0.065 mm. Rare. Found in volcanic tuff. No. 387 γ .

Genus *DORYSPHÆRA*, Hinde.

The test is a simple latticed sphere, with a single radial spine. Secondary smaller spines are also occasionally present.

DORYSPHÆRA ECHINATA, sp. nov. (Pl. VIII, fig. 7.)

Test thin, the lattice-pores rounded or polygonal, unequal in size; the radial spine now slender and styliform, probably much stouter originally; the surface of the test is also covered with numerous minute secondary spines. Diameter of test, 0.1 mm.; width of larger pores, 0.01 mm.; length of radial spine, 0.1 mm. In siliceous limestone. No. 245 z. This species differs from those of the same genus in the Ordovician chert of Scotland by its smaller size and the secondary spines;¹ while its size and irregular pores also distinguish it from *Dorysphæra* (*Monostylus*) *hirsuta* (Cayeux).²

Genus *XIPHOSPHERA*, Haeckel.

The test is a simple latticed sphere, with two free radial spines in the same axis.

XIPHOSPHERA MINAX, sp. nov. (Pl. VIII, fig. 8.)

The test is relatively thick, the lattice-pores and bars are small and about equal in width, the spines long, stout, and with a central keel. They are now unequal in length, but this probably arises from their imperfect preservation. Diameter of test, 0.127 mm.; thickness, 0.02 mm.; width of pores, about 0.007 mm.; length of longest spine, 0.3 mm., and thickness at base, 0.045 mm. In siliceous limestone. No. 245 z. This form approaches near to *X. macrostyla*, Rüst, from the Upper Devonian of the Harz,³ but the pores are smaller and the spines longer.

Genus *STYLOSPHERA*, Ehrenberg.

The test consists of two concentric latticed spheres, with two opposite radial spines.

STYLOSPHERA OBTUSA, sp. nov. (Pl. VIII, fig. 9.)

The cortical test has a thin wall and smooth surface. The lattice-pores are wider than the bars between them. The medullary sphere is only faintly shown; the pores in it are small and delicate. This inner test is connected with the outer by the basal portion of the spines, which are stout, keeled, gradually tapering and obtusely pointed. Diameter of test, 0.115 mm.; thickness of wall, 0.01 mm.; width of pores, 0.0075 mm.; diameter of inner sphere, 0.045 mm.; length of spines, 0.22 mm., and thickness at base, 0.045 mm. In volcanic tuff. No. 387 d.

¹ Ann. & Mag. Nat. Hist. ser. 6, vol. vi (1890) pp. 52-53 & pls. iii & iv.

² 'Étude microgr. des Terr. sédiment.' 1897, p. 189 & pl. vii, fig. 12.

³ Palæontographica, vol. xxxviii (1892) p. 141 & pl. ix, fig. 10.

STYLOSPHÆRA VETUSTA, sp. nov. (Pl. VIII, fig. 10.)

The cortical sphere is only shown in section; the wall is thin, and the pores are small; the medullary sphere is smooth, with delicate somewhat subangular pores. The spines very gradually taper. Diameter of cortical test, 0·11 mm.; of medullary test, 0·04 mm.; length of spines, 0·105 mm., and thickness at base, 0·02 mm. In volcanic tuff. No. 387 d.

Genus *STAUROSPHÆRA*, Haeckel.

The test is a simple latticed sphere, with four equal radial spines disposed crosswise.

STAUROSPHÆRA (?) *ORNATA*, sp. nov. (Pl. VIII, fig. 11.)

Surface of the test smooth, wall moderately thick, pores rounded, unequal, the lattice-bars about half the width of the pores. Only one of the four spines is now intact; this is tapering, keeled, and has, at its extremity, four minute rays or spines diverging at right angles. Of the other spines, two are only indicated by short stumps, and the termination of the fourth is concealed. Diameter of test, 0·095 mm.; thickness, 0·01 mm.; length of spine, 0·12 mm., and thickness at base, 0·022 mm. In volcanic tuff. No. 387 d.

STAUROSPHÆRA PUSILLA, sp. nov. (Pl. VIII, fig. 12.)

Test small, wall thin, with irregular, large and small, subangular pores and slender lattice-bars; the radial spines are short, keeled, and acutely pointed. Only three are shown, the place of the fourth being concealed by matrix. The interior of the test has six or more slender rods radiating from the ends of a short central bar of the same character as those in the genus *Stigmospheera*, Haeckel. Diameter of test, 0·065 mm.; width of largest pores, 0·015 mm.; length of spine, 0·04 mm., and thickness at base, 0·02 mm. Rare. Found in volcanic tuff. No. 387 d.

Genus *STAUROLONCHE*, Haeckel.

The test consists of two concentric latticed spheres, with four simple, equal, radial spines disposed crosswise.

STAUROLONCHE DAVIDI, sp. nov. (Pl. VIII, fig. 13.)

The cortical test has numerous small surface-spines and circular pores. The radial spines are stout, keeled, and terminate obtusely. The inner sphere has minute rounded pores. Diameter of test, 0·11 mm.; of the medullary sphere, 0·05 mm.; length of spines, 0·15 mm., and thickness at base, 0·035 mm. This form appears to be very common in the dark siliceous limestones of Tamworth, but as a rule the spines are seldom preserved intact, and in the specimen figured only one is complete. Some of the forms figured by Prof. T. W. E. David¹ probably belong to this species.

¹ Proc. Linn. Soc. N.S.W. ser. 2, vol. xi (1896) pl. xxxviii, figs. 1, 4 & 8.

STAUROLONCHE TENELLA, sp. nov. (Pl. VIII, fig. 14.)

The cortical test is only shown in section; the wall is slender, with rounded pores; the inner sphere is very delicate, and the pores are circular. The spines are keeled and slightly longer than the diameter of the test. Diameter, 0.09 mm.; of inner sphere, 0.04 mm.; length of spines, 0.11 mm., and width at base, 0.022 mm. In siliceous limestone. No. 245 s.

STAUROLONCHE LATERNA, sp. nov. (Pl. VIII, fig. 15.)

The cortical test is only shown in section; the wall is moderately thick and minutely spined; the medullary test is somewhat octahedral in form; the pores are subangular, and very unequal in size. The spines are keeled or prismatic in section; their axes are not at right angles to each other. Diameter of the outer test, 0.095 mm.; of the inner, 0.04 mm.; length of spine (beyond the test), 0.07 mm., and width at base, 0.015 mm. In volcanic tuff. No. 387 d. The structure of the medullary test readily characterizes this species.

STAUROLONCHE SCITULA, sp. nov. (Pl. VIII, fig. 16.)

Cortical test with thick walls and small pores; the medullary sphere is very delicate, and the pores are subangular. Only two of the radial spines are preserved; they are slender, apparently circular in section, and very gradually taper to a point. Secondary surface-spines are also present. Diameter of test, 0.1 mm.; of the inner sphere, 0.042 mm.; length of spines, 0.11 mm., and thickness, 0.005 mm. Rare. Occurs in volcanic tuff. No. 387 d.

Genus *STAUROLONCHIDIUM*, Haeckel.

Test of two concentric latticed spheres, with four radial spines in two different pairs.

STAUROLONCHIDIUM OBLIQUUM, sp. nov. (Pl. VIII, fig. 17.)

The cortical test is thin, with small circular pores and surface-spines; the medullary test delicate, with polygonal pores. The spines are keeled; those forming the transverse axis are imperfect, but they appear smaller than those of the vertical axis. Diameter of cortical test, 0.11 mm.; of medullary test, 0.06 mm.; width of pores, 0.009 mm.; length of vertical spine, 0.21 mm., and width at base, 0.035 mm. In siliceous limestone. No. 245 s.

Genus *TRILONCHE*,¹ gen. nov.

The test consists of two concentric latticed spheres, with three radial spines at equal or unequal distances apart. Secondary surface-spines are also sometimes present. The forms included in this genus are very numerous in the Tamworth radiolarian rocks.

¹ Τρεῖς λόγχοι: three spears.

TRILONCHE VETUSTA, sp. nov. (Pl. VIII, fig. 18.)

The cortical test, as seen in section, is thin, with small lattice-pores and surface-spines; the inner test has minute circular pores enclosed by a polygonal framework; the radial spines are moderately stout, keeled or prismatic, subequal in length, and at unequal distances apart: they appear to be in the same plane. The proximal end of the spines is stout, and connects the medullary with the cortical sphere. Diameter of outer test, 0.095 mm.; of inner test, 0.045 mm.; length of spines, 0.09 mm., and thickness at base, 0.025 mm. In volcanic tuff. No. 387 d.

TRILONCHE VETUSTA, var. *a*. (Pl. VIII, fig. 19.)

This form is very similar to the preceding, but the surface appears to be smooth and the pores of the test somewhat finer. In addition to the three normal spines, which are unequal in length and in their distance apart, there is a small supernumerary radial spine. Diameter of cortical test, 0.1 mm.; of medullary test, 0.042 mm.; length of spines, 0.06 to 0.09 mm., and thickness at base, 0.025 mm. In volcanic tuff. No. 387 d.

TRILONCHE PITTMANI, sp. nov. (Pl. VIII, figs. 20 & 21.)

Cortical test with small pores; medullary test very delicate; pores circular; radial spines stout, keeled, unequal in length, and at nearly equal distances from each other. Of the two specimens figured, fig. 20 measures 0.15 mm. in diameter, the medullary test being 0.055 mm. in diameter, the spines 0.19 to 0.26 mm. long, and 0.035 mm. thick. In fig. 21 the cortical test is 0.115 mm. in diameter; the medullary test has not been preserved; the spines are 0.1 to 0.15 mm. long, and 0.035 mm. thick. The figured specimens are from volcanic tuff, No. 387 d; similar forms are also common in the dark siliceous limestones of the Temporary Common, Tamworth. No. 245 z.

TRILONCHE ELEGANS, sp. nov. (Pl. VIII, fig. 22.)

The cortical test is only shown in section; the wall is thin, with small pores; the medullary test is about half the diameter of the cortical; the pores are subcircular, with a delicate polygonal framework. The radial spines are short, conical, nearly equal in length, but at unequal distances apart. Diameter of test, 0.09 mm.; of inner sphere, 0.047 mm.; length of radial spines, 0.04 mm. In siliceous limestone. No. 245 z.

Genus *ACANTHOSPHERA*, Ehrenberg.

The test is a simple latticed sphere, with eight or more radial spines of the same kind.

ACANTHOSPHERA AUSTRALIS, sp. nov. (Pl. VIII, fig. 23.)

Only sections of this form are shown; the spines are short, robust, conical, and somewhat unequal in length, but of the same kind;

there are nine exposed in the section; the pores are about as wide again as the lattice-bars between them. There are indications of siliceous rods, like those of *Stigmospæra*, within the test. Diameter of test, 0.135 mm.; thickness of wall, 0.01 mm.; width of pores, 0.01 mm.; length of spines, 0.02 to 0.06 mm., and thickness at base, 0.015 to 0.02 mm. Rare. In volcanic tuff. No. 387 d.

ACANTHOSPHERA *ETHERIDGEI*, sp. nov. (Pl. VIII, fig. 24.)

Test small, with delicate lattice-frame and circular pores; the spines are slender and elongate: nine are shown in the specimen. In the interior of the test there are six rods, three radiating from each end of a small central bar; they extend to the surface of the test, and apparently connect with the radial spines. Diameter of test, 0.085 mm.; width of pores, 0.01 mm.; longest spine, 0.14 by 0.01 mm. at the base. In volcanic tuff. This species is closely related to *A. laxa*, Hinde & Fox, from the Culm of Devon,¹ but it is considerably smaller. It is named in honour of Mr. Robert Etheridge, jun., of the Australian Museum, Sydney.

Genus *HELIOSPHERA*, Haeckel.

The test is a simple latticed sphere, with large radial and intermediate smaller secondary spines.

HELIOSPHERA *ROBUSTA*, sp. nov. (Pl. VIII, fig. 25.)

The test, as seen in section, has thick walls, with pores about half as wide again as the lattice-bars; six primary radial spines, of varying length, are shown: they are prismatic in section. The secondary spines are very minute, and they seem to be present on each node of the mesh. Portions of siliceous rods are seen within the test. Diameter of test, 0.14 mm.; thickness, 0.015 mm.; width of pores, 0.01 mm.; length of spines, 0.025 to 0.1 mm., and thickness at base, 0.02 to 0.03 mm. Rare. Occurs in volcanic tuff. No. 387 d.

HELIOSPHERA *TAMWORTHII*, sp. nov. (Pl. VIII, fig. 26.)

The pores in the test are slightly wider than the lattice-bars; the larger radial spines are conical, and evenly tapering: nine of them are shown in the section; the secondary spines differ only in size from the larger. Diameter of test, 0.14 mm.; thickness, 0.01 mm.; length of primary spines, 0.06 to 0.1 mm.; thickness at base, 0.02 mm. Differs from the preceding in its thinner walls, more tapering primary and larger secondary spines. In siliceous limestone. No. 245 s.

HELIOSPHERA *FENESTRATA*, sp. nov. (Pl. VIII, fig. 27.)

The test has rounded and oval pores of different sizes, with relatively wide lattice-bars. The larger spines are elongate-conical; they are connected with the test by slender tripodal extensions of their bases. The secondary spines are numerous and minute.

¹ Quart. Journ. Geol. Soc. vol. li (1895) p. 637 & pl. xxvi, fig. 6.

Diameter of test, 0·105 mm.; width of pores, 0·005 to 0·015 mm.; length of radial spine, 0·1 mm.; of secondary spines, 0·01 mm. In the specimen figured the radial spines are broken away, and only their stumps remain; but a complete spine, in position on another specimen, is shown in the figure. In siliceous limestone. No. 245 3.

HELIOSPHERA CLAVATA, sp. nov. (Pl. VIII, fig. 28.)

Framework of test delicate; the pores are rounded or polygonal, and unequal in size; there are four or five robust primary spines shown: these taper very gradually, and terminate obtusely; the secondary spines are conical and pointed. Diameter, 0·075 mm.; width of pores, 0·0075 mm.; length of primary spines, 0·1 mm.; thickness, 0·022 mm. In siliceous limestone. No. 245 3.

Genus *HELIOSOMA*, Haeckel.

The test consists of two latticed spheres (a cortical and a medullary), with large radial, and smaller and more numerous secondary spines.

HELIOSOMA ECHINATUM, sp. nov. (Pl. IX, figs. 1 & 2.)

The cortical test has small lattice-pores; the medullary test is small, with very slender lattice-framework and polygonal pores; the larger radial spines are robust and gradually tapering, the smaller are very numerous, slender needle-shaped, and unequal in length. Diameter of cortical test, 0·16 to 0·22 mm.; thickness of wall, 0·015 mm.; diameter of medullary test, 0·05 mm.; length of primary spine, 0·27 mm.; thickness at base, 0·03 mm.; secondary spines, 0·02 to 0·1 mm. in length. Not uncommon. Occurs in volcanic tuff. No. 387 D.

Only sections of this form are as yet known, and in the specimens figured one alone of the radial spines in each case is preserved, but there are indications of the broken-off bases of others. The radial spine of fig. 1 probably represents merely the central portion of the spine; it may originally have been equally as stout as that in fig. 2. The medullary test is faintly shown in fig. 1, but cannot be distinguished in fig. 2, which is infilled with somewhat granular silica. Both the figured specimens occur in the same microscopic section of the rock.

HELIOSOMA PARONÆ, sp. nov. (Pl. IX, fig. 3.)

In its main features this form resembles the preceding, but the pores of the outer test are circular; the medullary test has not been preserved; the secondary spines are of a stout character, and there is the lower portion of an unusually thick radial spine. Diameter of test, 0·16 mm.; width of pores, 0·01 mm.; basal thickness of radial spine, 0·04 mm.; length of secondary spines, 0·11 mm. Rare. In siliceous limestone. No. 245 3. Named in honour of Prof. C. F. Parona, of Turin.

Order PRUNOIDEA, Haeckel.

Genus ELLIPSIDIUM, Haeckel.

The test is a simple latticed ellipsoid, with radial spines on its surface.

ELLIPSIDIUM CASTANEA, sp. nov. (Pl. IX, fig. 4.)

Test small, with subequal rounded pores and lattice-bars about half the width of the pores; the spines are short and conical. Major axis of test, 0.095 mm.; minor, 0.075 mm.; width of pores, 0.01 mm.; length of spines, 0.015 mm. Rare. In siliceous limestone. No. 245 s.

Genus ELLIPSOSTIGMA,¹ gen. nov.

The test is a simple latticed ellipsoid, with four radial spines, which proceed from a central spot or a short bar in the centre of the test. Secondary spines are also present.

The nearest genus with which this may be compared is *Stigmosphaerostylus*, Rüst, in which six radial bars extend from the centre of a spherical test.²

ELLIPSOSTIGMA AUSTRALE, sp. nov. (Pl. IX, fig. 5.)

The test is oval, with minute rounded pores; in the centre four straight rods extend from a small bar in different directions to beyond the circumference of the test, so as to form short conical spines. Minute secondary spines arise from the nodes of the mesh. Major axis of test, 0.12 mm.; minor, 0.1 mm.; width of pores, 0.006 mm.; radial spines, 0.03 mm. Rare. In siliceous limestone. No. 245 s.

Genus STAURODRUPPA,³ gen. nov.

The test consists of two concentric latticed ellipsoids, cortical and medullary, with four radial spines, disposed crosswise in two axes, but not always at right angles. The radial spines may all be similar, or those of the same axis may be similar; but, owing to the imperfect preservation in the fossil forms, this feature can seldom be ascertained with certainty. This genus corresponds with *Staurolonche*, Haeckel, and *Staurolonchidium*, Haeckel, in the Sphaeroidea.

STAURODRUPPA PRÆLONGA, sp. nov. (Pl. IX, fig. 6.)

The cortical test has a smooth surface; the pores are about as wide as the lattice-bars. The medullary test is only shown in section. The radial spines appear to be in pairs; those of the major axis are prismatic, very long and stout, and those of the transverse

¹ Ἐλλειψίς, ellipse; στίγμα, spot.

² Palæontographica, vol. xxxviii (1892) p. 142.

³ Σταυρός, cross; δρύππα, olive.

short and slender. Major axis, 0·12 mm.; minor, 0·1 mm.; thickness of wall, 0·01 mm.; width of pores, 0·007 mm.; longest polar spine, 0·22 mm., and thickness at base, 0·045 mm.; transverse spine, 0·06 by 0·015 mm. The medullary test is 0·055 by 0·04 mm. In siliceous limestone. No. 245 z. The lower axial spine in the specimen figured is imperfect; it seems to have been originally as thick as the spine opposite to it.

STAURODRUPPA NUCULA, sp. nov. (Pl. IX, fig. 7.)

The cortical test is regularly oval in outline; the lattice-frame of the oval medullary test is very delicate; the pores are minute and rounded or subangular. The radial spines are keeled or prismatic, and nearly equal in length. Major axis of cortical test, 0·105 mm., and minor, 0·085 mm.; major and minor axes of inner test, 0·05 and 0·035 mm. Length of spines, 0·09 to 0·11 mm.; thickness at base, 0·03 mm. In siliceous limestone. No. 245 z.

STAURODRUPPA NANA, sp. nov. (Pl. IX, fig. 8.)

The cortical test small, short-oval, thin, with circular pores; the medullary regularly oval, very delicate, with subangular pores. The radial spines are short, slender, conical, probably imperfect. Outer test, 0·065 by 0·06 mm.; inner, 0·035 by 0·03 mm.; width of spines, 0·02 mm. Rare. In siliceous limestone. No. 245 z.

Genus *SPONGOCÆLIA*,¹ gen. nov.

The test is ellipsoidal, with an irregularly reticulate or spongy framework and central cavity, without medullary shell. There are two opposite radial spines, and within the test slender rods similar to those in *Stigmospæra*, Haeckel, or a central spicular body.

This genus may be compared with *Spongoprunum*, Haeckel,² in which, however, the interior cavity of the test is filled with a reticulate or spongy structure.

SPONGOCÆLIA CITREUM, sp. nov. (Pl. IX, fig. 18.)

The test is regularly oval in outline, with a minutely porous wall of reticulate tissue, and within it are delicate siliceous rods, now displaced. At either pole there is a short, stout, keeled, radial spine, probably similar originally. Length of test, 0·165 mm.; width, 0·15 mm.; length of radial spine, 0·09 mm., and thickness at base, 0·05 mm. In volcanic tuff. No. 387 d.

SPONGOCÆLIA OLIVA, sp. nov. (Pl. IX, fig. 19.)

The test is oval, with a minutely reticulate structure; in the centre there is a small three-rayed spicular body. At one pole is a slender elongate radial spine, and at the opposite a much shorter one. Length of test, 0·125 mm.; breadth, 0·1 mm.; principal spine, 0·14 mm. in length. In siliceous limestone. No. 245 z.

¹ Σπόγγος, sponge; κοίλος, hollow.

² *Challenger* Report on the Radiolaria, Zool. vol. xviii, pt. i (1887) p. 347.

Order DISCOIDEA, Haeckel.

Genus THEODISCUS, Haeckel.

The test is a simple latticed disc, with three marginal radial spines at equal or unequal distances apart.

THEODISCUS HASTATUS, sp. nov. (Pl. IX, fig. 9.)

Test small, with rounded pores and slender, polygonal lattice-bars. Radial spines robust, keeled, and acutely pointed, at unequal distances apart. Diameter of test, 0.075 mm.; width of lattice-pores, 0.005 mm.; length of spines, 0.08 to 0.15 mm.; thickness at base, 0.025 mm. In volcanic tuff. No. 387 D.

Genus TROCHODISCUS, Haeckel.

The test is a simple latticed disc, with ten or more marginal radial spines.

TROCHODISCUS PLANATUS, sp. nov. (Pl. IX, fig. 10.)

Test compressed, with rounded subequal pores and bars about half the width of the pores. A number of stout, short, conical spines extend from the margins. In the centre of the test is a minute three-rayed spicule, closely resembling the detached forms which have been referred to *Sphaerzoum*. Diameter of test, 0.17 mm.; width of lattice-pores, 0.01 mm.; length of spines, 0.02 to 0.05 mm. In siliceous limestone. No. 245 3.

Genus TRIACTISCUS, Haeckel.

The latticed disc has a simple medullary test, and three radial spines on the margin.

TRIACTISCUS LANCEOLA, sp. nov. (Pl. IX, fig. 11.)

The cortical test has very minute rounded pores; the lattice-bars are nearly as wide as the pores, and are furnished with minute spines. The medullary test is only indicated by a fragment of the mesh, with pores larger than those of the cortical test. Of the radial spines only two are preserved, and one of these is imperfect; the other is lanceolate in form, with a strong longitudinal keel. Diameter of cortical test, 0.105 mm.; width of pores, 0.005 mm.; radial spine: length, 0.115 mm., and greatest width, 0.04 mm. In volcanic tuff. No. 387 D.

Genus DISTRIACTIS, Haeckel.

The latticed disc has a simple medullary test, and six radial spines extending from the margin in the equatorial plane.

DISTRIACTIS VETUSTA, sp. nov. (Pl. IX, fig. 12.)

Both the outer and inner tests are oval in outline; the pores of

the medullary test are rounded; the radial spines are slender, conical, now unequal in length, probably due to imperfect preservation: the longest equals the radius of the test. The proximal ends of the spines extend for a short distance within the medullary test. Diameter of cortical test, 0·15 by 0·13 mm.; of medullary, 0·05 mm.; of pores, 0·008 mm.; longest spine (measured from margin of test) 0·07 mm., and thickness, 0·01 mm. Rare. In siliceous limestone. No. 245 a.

Genus *HELIOSESTRUM*, Haeckel.

The test is similar to that of *Distriactis*, but the radial spines are eight in number; occasionally there are seven or nine.

HELIOSESTRUM NIGRUM, sp. nov. (Pl. IX, fig. 13.)

The test is only shown in section; it is slightly oval in outline; the medullary test is about one-third the diameter of the cortical; there are eight radial spines, but only one of these is preserved complete; it is about twice the diameter of the disc, and slightly curved near the end. Diameter of outer test, 0·135 by 0·11 mm.; of inner, 0·038 mm.; length of spine, 0·24 mm., and thickness, 0·02 mm. In siliceous limestone. No. 245 a.

Genus *SPONGODISCUS*, Haeckel.

The test is a flattened disc, of irregularly reticulate or spongy structure throughout, without marginal appendages.

SPONGODISCUS PUNCTUS, sp. nov. (Pl. IX, fig. 14.)

The disc is nearly circular in outline, with very minute pores and irregularly reticulate framework without radial bars. Diameter, 0·14 mm.; pores, about 0·003 mm. Rare. In volcanic tuff. No. 387 d.

SPONGODISCUS ACINUS, sp. nov. (Pl. IX, fig. 15.)

The test is oval in outline, depressed, the structure minutely reticulate, and the margin is roughened with small prickles. Diameter of test, 0·09 mm. Closely allied to the preceding; it may be distinguished by its prickly surface and oval outline. Rare. In siliceous limestone. No. 245 a.

SPONGODISCUS CRIBRARIUS, sp. nov. (Pl. IX, fig. 16.)

The test is nearly circular in outline, depressed; the reticulate structure is minute, though less so than in the preceding species, and the pores are consequently larger. No radial bars. Diameter of test, 0·2 mm.; width of pores, 0·005 to 0·01 mm. Rare. In volcanic tuff. No. 387 d. This form may be compared with *Sp. expansus*, Hinde, from the Cretaceous at Fanny Bay, Port Darwin, which has a finer structure.¹

¹ Quart. Journ. Geol. Soc. vol. xlix (1893) p. 224 & pl. v, fig. 6.

SPONGODISCUS SCUTULATUS, sp. nov. (Pl. IX, fig. 17.)

The test is elongate-oval in outline, depressed; the central area is nearly free from tissue, but there is no definite inner test; the structure is very minute and irregularly reticulate, with numerous radial bars, which are not extended beyond the margin. Length of test, 0·185 mm.; breadth, 0·12 mm.; width of pores, 0·005 mm. In siliceous limestone. No. 245 z.

Genus *SPONGOLONCHE*, Haeckel.

Test discoidal, of irregular reticulate or spongy structure, with two opposite radial spines.

SPONGOLONCHE LENS, sp. nov. (Pl. IX, fig. 20.)

The test is elongate-oval; the wall-structure is minutely porous; the reticulate tissue is disposed in four or five concentric layers, and there are also traces of a radial arrangement as well. There is an oval space in the centre of the test, now partly filled with amorphous matrix. At either end of the main axis is a stout conical spine. Length of test, 0·22 mm.; breadth, 0·16 mm.; length of spines, 0·25 mm. and 0·185 mm. Rare. In siliceous limestone. No. 245 z.

Genus *SPONGOTRIPUS*, Haeckel.

Test discoidal, of porous, reticulate or spongy framework, with three solid radial spines on the margin.

SPONGOTRIPUS PATELLA, sp. nov. (Pl. IX, fig. 21.)

The test is depressed, rounded in outline; the surface-structure is irregularly reticulate, but beneath this the framework has a radial arrangement, and looks as if numerous slender bars extended from the borders of a central area in which no structure is shown. Only two radial spines are preserved. Diameter of test, 0·25 mm.; longest spine, 0·16 mm.; thickness at margin, 0·04 mm. Rare. In volcanic tuff. No. 387 d.

SPONGOTRIPUS FENESTRATUS, sp. nov. (Pl. IX, fig. 22.)

The test is oval in outline, depressed; the surface-reticulation in the central portion of the test has circular and subangular pores; nearer the margins the reticulations are finer, and a radial arrangement prevails. Two stout, conical, radial spines are preserved, and the base of a third. Diameters of test, 0·175 by 0·14 mm.; length of spines, 0·1 to 0·115 mm., and thickness, 0·035 mm. In siliceous limestone. No. 245 z. The upper part of the specimen figured is incomplete.

Subclass *NASSELLARIA*, Ehrenberg.

Order PLECTOIDEA, Haeckel.

The rudimentary skeleton consists of simple or branched radial spines, arising from a common central point or central rod. The branched spines may be connected together by a loose, open mesh-work.

Genus *PLAGIACANTHA*, Claparède.

The skeleton is formed by three radial spines arising from a common central point, and corresponding to the edges of a three-sided pyramid.

PLAGIACANTHA AUSTRALIS, sp. nov. (Pl. IX, fig. 23.)

Only two of the spines and the basal portion of the third are shown; they are nearly straight, simple, unequal in length, circular in section, and gradually tapering. On their upper surfaces there are close-set, minute pustules or blunted spines. Length of spines, 0.215 to 0.18 mm.; thickness at centre, 0.02 mm. In siliceous limestone. No. 245 z.

Genus *PLAGONISCUS*, Haeckel.

The skeleton consists of four unequal radial spines arising from a common central point: one vertical or apical spine being opposed to three divergent or basal spines.

PLAGONISCUS SIMPLEX, sp. nov. (Pl. IX, fig. 24.)

The three basal spines are simple, straight, conical, and in one plane; the vertical spine slender and curved. Length of basal spines, 0.06, 0.07, 0.08 mm.; thickness, 0.01 mm.; length of vertical, 0.085 mm. In siliceous limestone. No. 245 z.

PLAGONISCUS CRISTATUS, sp. nov. (Text-fig a, p. 57.)

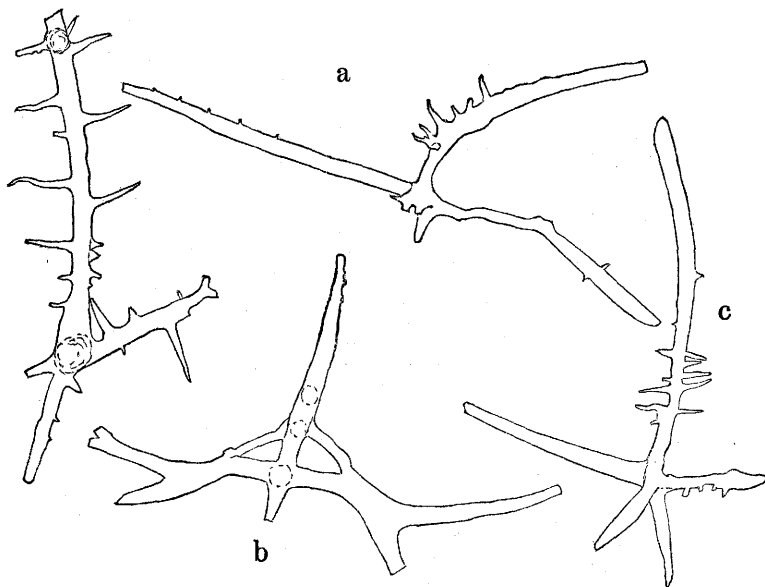
The basal spines, of which only two are shown, are simple, uneven, with minute prickles; the apical spine curved, compressed, with stout prickles on one edge. Length of basal spines, 0.18 and 0.22 mm.; thickness, 0.012 mm.; length of apical spine, 0.18 mm. In siliceous limestone. No. 245 z.

PLAGONISCUS COLLIGATUS, sp. nov. (Text-fig. b, p. 57.)

The apical spine is fusiform, tapering to both ends and with very minute prickles near its point; the basal spines, of which only two are shown, are straight near their origin, they are then bent downwards and become furcate; the rays are unequal. The basal spines are connected with the apical by oblique siliceous beams. Length of apical spine, 0.185 mm.; thickness, 0.015 mm.; length of basal spine to end of furcate ray, 0.185 mm. Rare. In siliceous limestone. No. 245 z.

PLAGONISCUS (?) *VETUSTUS*, sp. nov. (Text-fig. c, below.)

The apical spine is elongate, with projecting lateral spines on either margin; the basal spines are straight or slightly curved: they are now imperfect. Beneath the central point is a short straight spine, which may either be an extension of the apical spine or an independent spine; in this latter case the form can hardly be included in *Plagoniscus*. Length of apical spine, 0.24 mm.; thickness, 0.015 mm.; the longest basal spine measures 0.105 mm. In siliceous limestone. No. 245 a.



[The figures are all magnified 200 diameters.]

a = *Plagoniscus cristatus*, sp. nov.

b = *Pl. colligatus*, sp. nov.

c = *Pl. (?) vetustus*, sp. nov.

d = *Pl. (?)* sp.

PLAGONISCUS (?) sp. (Text-fig. d, above.)

This form has, like the preceding, a short spine below the central point of the basal spines and the apical; both the apical and basal spines are furnished with stout marginal prickles projecting at right angles. Length of apical spine (imperfect), 0.2 mm.; thickness, 0.015 mm. In the same rock with the preceding.

The following list shows the genera, and the numbers of species in each genus, of radiolaria, which have been recognized in the Devonian rocks at Tamworth (New South Wales):—

Order	BELOIDEA.	Species.	Order	PRUNOIDEA.	Species.
	<i>Sphærozoum</i>	1 ?		<i>Ellipsidium</i>	1
				<i>Ellipsostigma</i>	1
Order	SPHÆROIDEA.			<i>Staurodruppa</i>	3
	<i>Cenosphaera</i>	2		<i>Spongocælia</i>	2
	<i>Liosphaera</i>	1			
	<i>Rhodospheera</i>	1	Order	DISCOIDEA.	
	<i>Spongoplegma</i>	1		<i>Theodiscus</i>	1
	<i>Doryspheera</i>	1		<i>Trochodiscus</i>	1
	<i>Xiphospheera</i>	1		<i>Triactiscus</i>	1
	<i>Stylosphaera</i>	2		<i>Distriactis</i>	1
	<i>Staurosphaera</i>	2		<i>Heliosestrum</i>	1
	<i>Staurolonche</i>	4		<i>Spongodiscus</i>	4
	<i>Staurolonchidium</i>	1		<i>Spongolonche</i>	1
	<i>Trilonche</i>	3		<i>Spongotripus</i>	2
	<i>Acanthospheera</i>	2			
	<i>Heliosphaera</i>	4	Order	PLECTOIDEA.	
	<i>Heliosoma</i>	2		<i>Plagiacantha</i>	1
				<i>Plagoniscus</i>	5

Order.	No. of Genera.	No. of Species.
Beloidea	1	1
Sphæroidea	14	27
Prunoidea	4	7
Discoidea	8	12
Plectoidea	2	6
	<u>29</u>	<u>53</u>

IV. GENERAL CHARACTERS AND AFFINITIES OF THE RADIOLARIA.

From the preceding list it is seen that 53 species belonging to 29 genera of radiolaria have been determined from the Devonian rocks of Tamworth. Four genera and all the species are considered as new. The apparent absence of known species in these deposits will appear less remarkable when we remember that our present knowledge of Palæozoic radiolaria is limited to those occurring in a few outcrops in Central and Northern Europe, and that those herein described are the first known from older rocks in the Southern Hemisphere. Considering the great thickness of the Tamworth radiolarian deposits, and the immense number of the organisms in them, one might have anticipated that a greater variety of forms would be found. It is probable indeed that the 53 species figured do not represent a moiety of those present in the rocks, for comparatively few fragments of the beds have as yet been microscopically examined, and many of the organisms in these have had to be passed over as too fragmentary for description.

The distinguishing feature of the Tamworth radiolaria is the very large proportion of forms with central or medullary latticed tests and radial spines. A glance at the figures in the accompanying

plates shows the great number of forms possessing these characters, but the proportion is even larger than the figures suggest, for the forms without radial spines are comparatively rare, while the spined forms are so abundant that in some thin sections no others are recognizable. This remark, however, applies only to the dark siliceous limestones which have had the calcite removed by acid; for the radiolaria, in sections of the chert and of the claystones, appear for the most part to be simple spherical or elliptical forms without central tests and without radial spines. It is not at all probable that such marked differences of character should occur in the forms preserved in the cherts and claystones interstratified with the siliceous limestones, and the apparent absence of the spines and inner tests in the former beds may be attributed to the less perfect condition of preservation of the radiolaria contained in them.

As regards size, the Tamworth radiolaria appear to be relatively small. The tests, in the large majority, range between 0.06 and 0.25 mm. in diameter; exceptionally, larger forms occur: thus, for example, in a section of black chert (No. 274 e) a simple oval form measured 0.44 by 0.34 mm.

The order Sphæroidea is the most numerously represented in the Tamworth rocks; somewhat more than half the species are included in this division. With the exception of *Trilonche*, gen. nov., the species belong to genera previously recognized in Palæozoic rocks. With few exceptions these spheroidal radiolaria possess radial spines.

Three of the 4 genera of Prunoidea are new; they are characterized mainly by the development of the radial spines in connexion with the ellipsoidal test.

The 12 species of Discoidea belong to genera already known, but 5 out of the 8 genera of this division had not previously been recorded from Palæozoic rocks.

The only representatives of the subclass Nassellaria are spicular bodies included in the order Plectoidea. These simple forms might at first be mistaken for sponge-spicules, but neither in fossil nor in recent sponges are spicules, similar in detail to these, known to occur.

As negative features of the Tamworth radiolarian fauna may be mentioned the absence of the Discoidal genera *Lithocyclus*, *Porodiscus*, *Amphibrachium*, and *Rhopalastrum*, common in nearly all Mesozoic and Palæozoic radiolarian deposits hitherto described, and the yet more notable deficiency of any representative form of the order Cyrtoidæa.

The corals in the limestones associated with the radiolarian rocks at Tamworth (which have been determined by Mr. R. Etheridge, jun.) indicate clearly the Devonian age of the latter. The only rocks of this period containing radiolaria hitherto known are those described by Dr. H. Rüst from the Ural Mountains and from Hesse, considered to be Lower Devonian in age, and from the Harz and near Goslar, which are believed to be Upper Devonian.¹ From these

¹ Palæontographica, vol. xxxviii (1892) pp. 118, 114, 122.

rocks 64 species of radiolaria, belonging to 37 genera, were described, but only 7 of these genera are common with those at Tamworth, and no near relationship is apparent between the Devonian radiolaria of Central and Northern Europe and those of the same period in Australia. A similar want of affinity is also shown, if a comparison be made with the radiolaria of the Lower Culm or Carboniferous described by Rüst from the Harz, Sicily, Russia, etc.,¹ and by Hinde & Fox from the South-west of England.²

The Tamworth radiolaria, however, show as a whole a genera correspondence with the radiolarian fauna from the phosphorites and siliceous shales of Ordovician (Lower Silurian) age occurring at Cabrières in Languedoc, which have been described by Rüst,³ and also with that in the cherts of the Southern Uplands of Scotland of a corresponding age.⁴ In both these deposits the predominant radiolarian forms belong to the Sphæroidea with radial spines and medullary tests. In the Scottish beds they appear to belong rather to the group with spongiform than to that with regularly-latticed tests, but some doubt is thrown on this feature from the poor preservation of the fossils. In the same beds there are also some of the peculiar spicular bodies referred to primitive forms of Plectoidea, of a similar character to those at Tamworth. And finally it may be mentioned that the radiolarian fauna of Cabrières and Scotland resembles that of New South Wales in the absence of examples of the Cyrtoidæa.

The same features which distinguish the New South Wales Devonian radiolaria from those in the Palæozoic deposits of other areas serve still more strongly to mark them off from the radiolaria of Mesozoic and Tertiary rocks. In no respect is this difference more manifest than in the apparent absence of the Cyrtoidæa, which are so numerous represented in the Jurassic, Cretaceous, and Tertiary rocks that Haeckel stated in the *Challenger* Report⁵ that the majority of all the fossil radiolaria then known belonged to this group. This observation was made at a time when the existence of Palæozoic radiolaria had been scarcely recognized, but the evidence since obtained from Scotland, France, Germany, and now from New South Wales, points to the conclusion that the predominant forms of the Palæozoic radiolaria belonged to the Sphæroidea with medullary tests and radial spines, and that the Cyrtoidæa were either not represented or formed but a small minority of these organisms in the earlier radiolarian rocks.

V. FOSSILS ASSOCIATED WITH THE RADIOLARIA.

Judging from the rock-specimens that I have examined, other fossils besides radiolaria are extremely rare in the same beds, and

¹ Palæontographica, vol. xxxviii (1892).

² Quart. Journ. Geol. Soc. vol. li (1895) pp. 609-668.

³ Palæontographica, vol. xxxviii (1892) pp. 114, 122.

⁴ Ann. & Mag. Nat. Hist. ser. 6, vol. vi (1890) pp. 40-59.

⁵ Zool. vol. xviii, pt. ii (1887) p. 1126.

they are limited to a few spicules of siliceous sponges and some minute spined or dentate plates, probably of some invertebrate organism. The sponge-spicules are small, detached, fusiform acerates and cylinders, from 0.16 to 0.36 mm. in length, which probably belong to monactinellid sponges. No trace of any diatoms has been observed among the radiolaria of the siliceous limestones; if any had been present originally, it is probable that they would have been preserved, seeing that the equally delicate lattice-structures of the radiolaria have, in numerous instances, remained practically unaffected by the fossilization.

As mentioned by Messrs. David & Pittman, impressions of *Lepidodendron australe* are present in the same rock with numerous chalcedonic casts of radiolaria, and specimens of the same plant also occur in beds of tuff on two or three horizons. It may be rash to express an opinion without having seen the facts in the field, but it does not seem improbable that both the plant-fragments and the tuff may have been carried by the wind and wave-currents to some distance from land and deposited in deep water, in the same manner as the masses of leaves, pieces of bamboo, sugar-cane, and other débris which Prof. A. Agassiz dredged up from a depth of over 1000 fathoms, and at a distance of 10 to 15 miles from land, off Caribbean Islands.¹

It does not yet appear that radiolaria have been found in the bluish coral-limestone associated with the radiolarian series at Tamworth, which in places reaches a thickness of 1000 feet. In microscopic sections of this rock (No. 258 B) which I have examined there were only portions of corals which had been replaced by crystalline calcite. This rock has probably been formed under conditions, as to depth, different from those in which the radiolarian limestones and claystones were deposited.

VI. SUMMARY.

In the important series of radiolarian rocks, some thousands of feet in thickness, which have been traced out by Messrs. David & Pittman in New South Wales at Bingara, Barraba, and Tamworth, these organisms occur in beds of chert, siliceous limestones, claystones and shales, and in sedimentary volcanic tuffs. In the cherts the radiolaria are usually thickly grouped together, filling the rock; they are nearly entirely in the condition of casts infilled with clear silica and without structure, thus precisely similar to those in chert with radiolaria known in other parts of the world. In the siliceous limestones, on the other hand, the radiolaria not infrequently retain their delicate structures practically unaltered by fossilization; they are now embedded in a groundmass of crystalline calcite which has infiltrated their hollow spaces, and when this is eliminated by weak acid the rock is seen to be composed of an entangled tissue of entire and fragmentary forms and fine débris. The claystones

¹ 'Three Cruises of the *Blake*,' 1877-1880, Bull. Mus. Comp. Zool. vol. xiv (1888) p. 291.

are similarly filled with radiolaria which have been infiltrated by very fine clayey sediment, which is not removable by acid, and they are therefore less recognizable in microscopic sections, though they are shown weathered out on the surface of the rock. In the tuff-rock the radiolaria occur singly, scattered in the calcite which cements them and the tuff-fragments together; they retain their structures equally as well as those in the siliceous limestones, and, not being crowded, the details of their forms can be more readily distinguished in microscopic sections.

Fifty-three species, belonging to 29 genera, have been recognized; 4 genera and all the species are regarded as new, nearly all are included in the division of the Spumellaria, but a few primitive examples are referable to the Nassellaria. The predominant majority of the radiolaria are Sphæroidal and Prunoidal forms with medullary tests and radial spines. There is a singular absence of many Discoidal genera common in other fossil radiolarian faunas, and likewise of forms of Cyrtoidæa.

The geological age of the radiolarian rocks is proved to be Devonian by the occurrence, in the lower part of the Tamworth series, of corals characteristic of this period. The radiolaria, however, do not show any close affinity with those which have been described from Devonian rocks in Europe, but in some positive and negative characters they agree with those of Ordovician age from the South of Scotland, Cornwall, and from Cabrières in Languedoc.

As a rule, no other organisms beyond a very few simple sponge-spicules and some minute dentate plates of uncertain character occur in the same rocks with the radiolaria, but on two or three limited horizons fragments of *Lepidodendron australe* are present in claystones and tuffs, together with radiolaria.

In the coral-bearing limestones of the Tamworth section radiolaria have not as yet been found. On the other hand, in the radiolarian siliceous limestones no calcareous organisms have been recognized, and thus the source of the limestone in these rocks remains uncertain.

The radiolarian deposits of New South Wales are by far the most extensive of any hitherto known. For the formation of so great a thickness of rock, composed principally of extremely fine calcareous or clayey materials filled with the remains of these microscopic organisms, an enormous period of quiet sedimentation must be conceded. The radiolarian claystones of Tamworth may be compared with the recent red clays with radiolaria of the *Challenger* Report, and the tuff-rocks with the same forms sparsely scattered in them also find their parallel in the volcanic fragmentary materials which were dredged up by the *Challenger* from the depths of the Southern Ocean.

In conclusion I wish to express my great obligations to my friend, Mr. J. J. H. Teall, F.R.S., for his advice and assistance in ascertaining the character of the tuff-rocks containing radiolaria.

EXPLANATION OF PLATES VIII & IX.

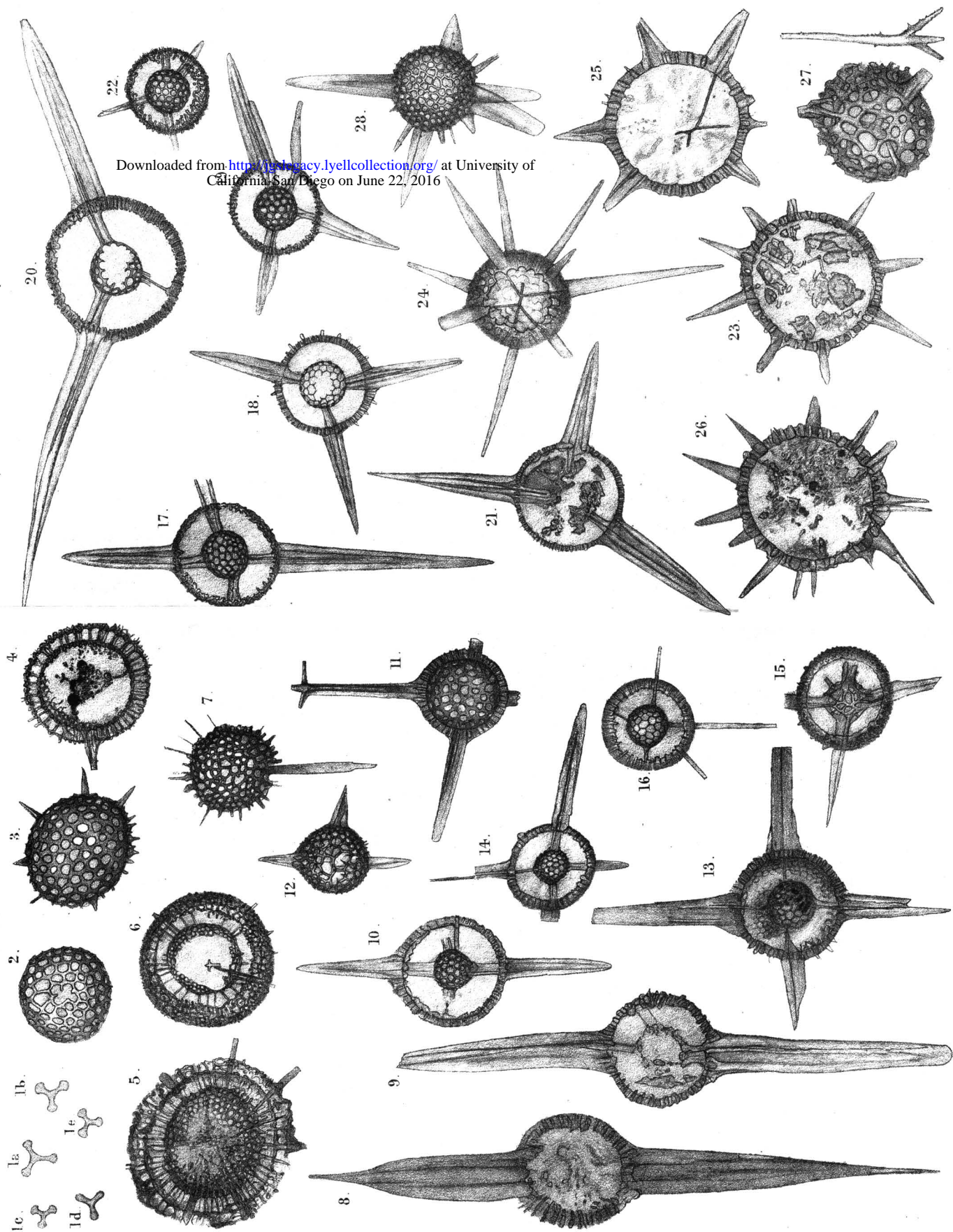
[The specimens figured are all from the Devonian rocks at Tamworth (New South Wales), and they are all drawn to the same scale of 200 diameters. The slides containing these specimens are in my own collection.]

PLATE VIII.

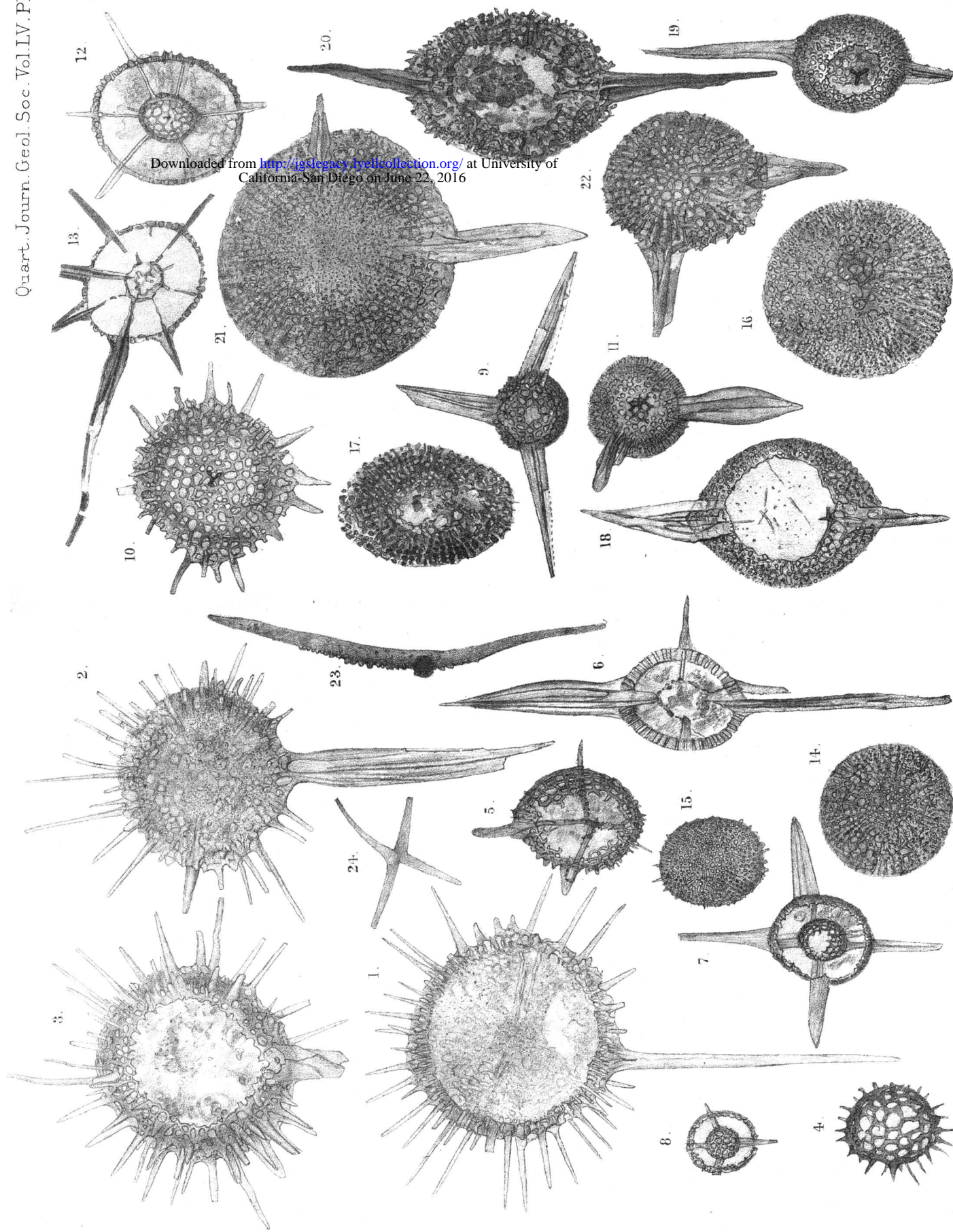
- Figs. 1 a-1 e. *Sphærozoum* sp. Detached, apparently three-rayed, spicules.
 Fig. 2. *Cenosphæra scitula*, sp. nov.
 3. " *affinis*, sp. nov.
 4. *Liosphæra*, sp. ind. Seen in section.
 5. *Rhodosphæra Ruesti*, sp. nov. Section.
 6. *Spongoplegma australe*, sp. nov.
 7. *Dorysphæra echinata*, sp. nov.
 8. *Xiphosphæra minax*, sp. nov. Section.
 9. *Stylosphæra obtusa*, sp. nov. Section.
 10. " *vetusta*, sp. nov. The outer test in section.
 11. *Staurosphæra (?) ornata*, sp. nov.
 12. " *pusilla*, sp. nov.
 13. *Staurolonche Davidi*, sp. nov.
 14. " *tenella*, sp. nov. The outer test in section.
 15. " *laterna*, sp. nov. " " "
 16. " *scitula*, sp. nov. " " "
 17. *Staurolonchidium obliquum*, sp. nov. The outer test in section.
 18. *Trilonche vetusta*, gen. et sp. nov. The outer test in section.
 19. " var. *a*. " " "
 20, 21. " *Pittmani*, sp. nov. " " "
 22. " *elegans*, sp. nov. " " "
 23. *Acanthosphæra australis*, sp. nov. In section.
 24. " *Etheridgei*, sp. nov.
 25. *Heliosphæra robusta*, sp. nov. In section.
 26. " *Tamworthi*, sp. nov. "
 27. " *fenestrata*, sp. nov. A specimen in which the spines are broken away; also one of the spines detached.
 28. " *clavata*, sp. nov.

PLATE IX.

- Figs. 1, 2. *Heliosoma echinatum*, sp. nov. In section.
 Fig. 3. *Heliosoma Paronæ*, sp. nov.
 4. *Ellipsidium castanea*, sp. nov.
 5. *Ellipsostigma australe*, gen. et sp. nov. In section.
 6. *Staurodruppa prælonga*, gen. et sp. nov. "
 7. " *nucula*, sp. nov.
 8. " *nana*, sp. nov.
 9. *Theodiscus hastatus*, sp. nov.
 10. *Trochodiscus planatus*, sp. nov.
 11. *Triactiscus lanceola*, sp. nov.
 12. *Distriactis vetusta*, sp. nov. In section.
 13. *Heliosestrum nigrum*, sp. nov. "
 14. *Spongodiscus punctus*, sp. nov.
 15. " *acinus*, sp. nov.
 16. " *cribrarius*, sp. nov.
 17. " *scutulatus*, sp. nov.
 18. *Spongocalia citreum*, gen. et sp. nov.
 19. " *oliva*, sp. nov.
 20. *Spongolonche lens*, sp. nov. In section.
 21. *Spongotripus patella*, sp. nov.
 22. " *fenestratus*, sp. nov.
 23. *Plagiacantha australis*, sp. nov.
 24. *Plagoniscus simplex*, sp. nov.



Downloaded from <http://legacy.lyellcollection.org/> at University of California San Diego on June 22, 2016



Downloaded from <http://igs.legacy.oxfordjournals.org/> at University of California-San Diego on June 22, 2016

Minter Bros. inc.

RADIOLARIA FROM THE DEVONIAN ROCKS OF NEW SOUTH WALES.
All $\times 200$ diameters

A.T. Hollick del et lith.

DISCUSSION (ON THE TWO FOREGOING PAPERS).

Mr. G. A. STONIER said that the paper was an important and very welcome contribution to the geology of the north-eastern portion of New South Wales, not only on account of the discovery of radiolaria, but also because *Lepidodendron australe* was shown to have had a greater range than had been previously supposed, and the position of the garnetiferous limestone had been ascertained. The tuffs were of particular interest to the speaker, as he had found that near the diamond-properties at Bingara tuffs and volcanic breccias were well developed; they contain fragmentary shells, and are interbedded with shales characterized by *Lepidodendron australe*.

Prof. SOLLAS, in complimenting the Authors on their work, commented on the shallow-water character of the deposits, and maintained that radiolarian cherts were by no means an infallible indication of abyssal conditions. The associated rocks in the Arenig Series, Culm Measures, and, as we now know, in the Devonian, were not of the nature of deep-sea deposits.

Prof. WATTS called attention to the great thickness of the radiolarian deposit, and remarked that the extraordinary point about this deposit and those in Devon, California, and Southern Scotland was the entire absence of terrigenous material. The thickness of the deposits indicated the lapse of a great interval of time.

Dr. HINDE, in reply, said that Prof. Sollas was under a misapprehension in supposing that several conglomerates were intercalated in the series of radiolarian rocks at Tamworth; the Authors referred to one conglomerate which occurred in the highest part of the section, and they doubted whether even this properly belonged to the beds below it. The speaker still considered that the radiolarian strata of New South Wales, also those of the South-west of England and California, indicated deposition at a distance from land and in deep water, though to Prof. Sollas this might seem an 'irrational conclusion.'

The PRESIDENT also spoke.