IX.—*On some Spheroidal Lithistid Spongida from the Upper Silurian Formation of New Brunswick.* By Prof. P. Martin Duncan, F.R.S.

[Plate IX.]

In 1875 Mr. G. J. Hinde, F.G.S., sent a number of fossils to the Geological Society with a short paper, which was published in abstract*. He described them as coming from the calcareous shale of Lower Helderberg or Upper Silurian age in New Brunswick, and felt disposed to classify them with the Tabulata; but he had not, at the time, the opportunity of amply examining them.

The spheroidal shape of the fossils and their evidently former free existence attracted my attention a few weeks since, as I was investigating the similarly shaped organic remains from the Himalayas, which have been classified under the order Syringosphæridæ amongst the Rhizopoda. Mr. Hinde very kindly allowed me to investigate the structure of the fossils he had sent; and this communication is the result of their examination.

The four specimens of the spheroidal fossils which have come under examination are oblate, symmetrical, rounded at the top and bottom, and slightly produced at the equatorial bulge. The heights are $\frac{7}{10}$, $\frac{6}{10}$, $\frac{5}{10}$ inch, and the breadths respectively $1\frac{3}{20}$ inch, 1 inch, and $\frac{9}{10}$ inch. It would appear that the growth was more in height than in breadth. The fourth specimen had been polished on its poles and equator in more than one place, and therefore could not be measured correctly.

The outside of the fossils is, where the organism has been preserved, minutely granular to the eye, and is covered with minute depressions between the granules. A low magnifying-power shows that the granules are separate, rounded, minutely irregular on their surface, about as high as broad, and that the three or four which are round each depression are imperfectly connected by low and narrow processes. The granules, however, are often broad and irregular, and form much of the sides of the depression; their general equality in size and the vast number of the pore-like spaces included by them are evident enough.

In some places on the surface, where the weathering has been greater, or where rubbing has removed more or less of it, and especially at the edges of the abrasion, the bottom of the

* "Description of a new Genus of Tabulate Coral. By G. J. Hinde, Esq., F.G.S." Abstracts of the Proc. Geol. Soc., No. 305.

pore-like depressions may be seen as spaces filled with dark homogeneous calcite. They are very minute, of different sizes, and oval, square, or more or less triangular in outline. There are no points projecting into them; and neither septa nor spiculate septa-like processes exist.

Where abrasion has been carried on so as to destroy the granules and partly to level the intermediate narrow processes, the structures become very comprehensible. A reticulate appearance is presented, the white calcareous meshes of the skeleton surrounding dark polygonal or oval spaces. The breadth of each space or reticulation is from $\frac{1}{150}$ to $\frac{1}{200}$ inch; and the sides are formed by narrow irregular cylinders, whilst the angles are swollen and faintly nodular. These nodular parts are the bases of the external granules. No septa or projections resembling those of the Perforata exist.

Slightly deeper abrasion and polishing exhibit indications of the junction of the irregular cylindrical sides of the meshes, sometimes at the nodules or angles, or in the midst of the cylinder, one part being received into the other. The swellings at the angles are less, but are still prominent features; and two conditions of the environed area are to be noticed: in one, and the most usual, the space is filled with clear dark calcite, and no structures are seen in it; in the other a white or opalescent film intrudes from the sides nearly to the centre, leaving there a small circular space of dark calcite. This second condition resembles an imperfect tabula belonging to an endotheca, such as is present in *Chætetes*. In many spaces there is perfect occlusion; but the texture of the substance thus simulating a perfect tabula, is not that of the calcareous mesh, it is that of infilling foreign matter. This is proved to be the case in radial sections.

The areas differ much in size; but none are very large, nor are any surrounded by sets of smaller ones in regular series. Their measurements correspond nearly with those given on the surface.

At this stage of the inquiry, if a good illumination is employed, with a magnifying-power of about 30 diameters, the latticework of the calcareous skeleton of the fossil, seen on a deepish abrasion, is found to consist of separate elements conjoined, each being resolvable into two prongs and a stem of the same thickness and length; and at their junction a nodular process or another stem exists. A triradiate or quadriradiate spicule with straight or bent limbs irregularly papillary here and there on the edge, is the element; and at the extremities of the limbs there are swellings not unlike frills, some being rather convex there and others concave; and the convexity

of one is embraced by the concavity of a neighbouring spicule.

Radial sections were made of some of the specimens, and were examined by reflected, transmitted, and polarized light. The dark-spot method of illumination was particularly successful. The powers employed were from 30 to 450 diameters; and the investigation was assisted by the action of dilute hydrochloric acid as a solvent.

The original hard parts are white and nearly opaque, and when cut across and polished are almost homogeneous, only minute granulation being visible under high powers. They consist of carbonate of lime, and are white by reflected light, and either colourless or light brown or grey by transmitted light, the central dark-spot illumination producing an exquisite surface-opalescence. Polarized light produces but slight colour; but it indicates a vast number of minute refractive points: crystals of calcite are not seen, however; and there are no cleavage-planes in the hard original parts. The fossils are infiltrated with clear transparent or rather dusky calcite with very few cleavage-planes, and in some places giving indications, under polarized light, of a more or less acicular or fibrous structure, like aragonite. Rhombs of calc spar exist here and there; and the intensity of the colours elsewhere, under the crossed Nicols, varies much. Near the periphery of the fossils, what may be termed orbicular calcite covers the skeleton and intrudes in undulating contours on the homogeneous calcite; and this margin acts differently on light to the mineral on either side of it. In a few places the margin looks almost membranous, if such a term is admissible, whilst within it and near the skeletal elements the structure is sometimes acicular and close, or it presents the usual appearance of infiltrated calcite. It is the projection of this orbicular layer, with or without drusy cavities, which gives the appearance of a semiclosure of the canals here and there.

On the whole, this remarkable layer is in the position of the mass of dermal spicules in some recent Lithistids; but no trace of any can be seen.

Radial sections through the centre of the fossils show that there is a small space in the centre which is occupied by an irregular reticulation of not universally continuous skeletal elements. The meshes are wide, and are either without any definite shape, or are quadrangular or pentagonal in outline. In one section there are separate spicules in the centre.

From the edges of this central space a great number of radiating, more or less straight canals pass to the periphery,

each being pervious throughout and without tabulæ. Each is in relation with those on all sides of it by means of regular three-, four-, or six-sided spaces in its walls. The canals are subequal; but here and there some are larger than the others. They arise from the central space, bifurcate occasionally, thus increasing in number, and end at the surface in the areas between the nodules and reticulation seen there. The largest canals measure $\frac{1}{75}$ inch in diameter, and the smallest about $\frac{1}{100}$ of an inch. Their length varies with the size of the specimen; for they constitute the larger part of the fossil.

They are more or less hexagonal or quadrangular in section, and are filled with the minerals already noticed. They were patent throughout before fossilization took place, and neither cross pieces, tabulæ, nor septa encroached on them; but it should be noticed that under a hand-lens tabulate structures appear very evident here and there; but they are resolved into parts of overhanging canal-walls under the compound microscope and careful focusing.

The canal-walls and their reticulation, as well as that on the outside, which is the expression of the outermost skeletal element of the canals, and the reticulation of the central part, are composed of similar structures, which are closely united in the first, and less so or separate in the last place.

The union of the spicules (for such are the skeletal elements) is often so intimate that the canal-walls appear to be continuous. But in thin sections, and in certain places in others, the skeleton resolves itself into numerous combinations of spicules closely resembling those of the Tetraclade Lithistidæ in shape and method of junction.

These canal-wall spicules resemble those which are free or nearly so in the central space. In no instance, however, has a central canal, or a canal in the three or four arms of a spicule, been observed.

Typical spicules, from the central space, consist of three arms in one plane uniting at a common point, from which another arm may spring and be in a plane at right angles, more or less, to the others. These tripod-stemmed spicules are often ragged or papillate on one or more surfaces, appear solid under the microscope, and are often compressed. They differ in size, and are usually the largest in the outer parts of the central space, where the canal-system is commencing. The simplest form of spicules has two straight or slightly curved arms, which are widely apart, forming an angle of 35° to 45° where they meet and join a smaller and shorter third, which lies in a different plane. The larger arms are flattish; and their opposed surfaces (sometimes the others) are nodular or

marked with irregular swellings, but the rest plain. Their tips are slightly expanded and faintly frilled. The smaller arm is nearly cylindrical, but more or less conical.

Under transmitted light these spicules appear nearly homogeneous; but polarized light enables minute granules, crystals, and very rarely cleavage-planes to be seen; nevertheless the refraction of the mineral is insufficient to produce much colour on crossing the Nicols.

The breadth of the arms is from $\frac{1}{500}$ to $\frac{1}{350}$ of an inch; and the length is from $\frac{1}{75}$ to rather more than $\frac{1}{100}$ inch. Some of these spicules, whilst retaining their general typical form, differ much in external aspect. They may have two arms slightly bent, expanded at the end, and rough (not on the sides forming the angle), and the third visible arm may be stunted; or the arms may be equal and straight, with a fourth like a well-developed knob or a long shaft.

Spicules from the canal-system are invariably joined with their neighbours to form a latticework. They consist of normal trifid forms, of trifid forms with short and large third limbs, of four-limbed forms, the extra limb resembling the others or longer or shorter. In some the fourth limb is situated at the junction of the other three, and, being in a plane at right angles to them, produces a general swelling at the junction, so as to interfere with the angle of the union of the limbs, it being occasionally replaced by a concavity or even a slight swelling. The limbs are usually plain on one side and roundedly dentate, or irregularly rounded and slightly spinose. The junction of the spicules with their neighbours may take place through the ends of the limbs uniting in a kind of suture, or by a joining which leaves no indication of its exact position. The skeleton thus formed is very irregular at the outer part of the central space, and then, as the canal-system commences, becomes very regular. The symmetrical arrangement of the spicules of the sides of the canals is very exact; and one canal is separated from its neighbours by common latticed walls. The diameter of the canal-space is greater than that of any of the openings in its walls; and the one is produced by four or five spiculate series extending around a space; and the others are the spaces left between the arms of neighbouring spicules.

The junction of the spicules is usually by the ends of the limbs; and the exceptions are rare; but in the centre of the body of the fossil instances are to be seen where the end of the limb of one spicule is attached to the middle of the cylindrical limb of another. The method of normal junction of different spicules is by the clasping and surrounding of a

smaller limb by a frilled or irregular cup-shaped expansion of a slightly larger; and the line of suture is visible. It often happens that the spicules do not quite touch, and the expanded limb-end of one and the corresponding smaller termination of the other and opposite limbs are separated by a microscopic interval. Sometimes one limb, frilled or digitate or simply rounded, projects, without that of any other spicule being near; and deformed specimens of these solitary parts are not unusual. Here and there the junction, as has been noticed already, is by direct fusion; and this occurs in the broad flat spicules of the canals more than elsewhere.

As the canals are close, and radiate to the periphery, increasing in number by bifurcation not far from the limits of the central space, each one must be surrounded by several others. Four, five, or six canals may environ the canal under observation; and a tangential section closely reproduces the appearance seen in abraded specimens when looking down on the reticulate ends of the canal-skeleton from the outside. Each canal is therefore polygonal in section (tangential). There is no duplication of the wall of a canal; and this structure is merely the space left by the interlacement of numerous sets of spicules in longitudinal series.

The symmetry of the parts of these spheroidal fossils is great; and there is a very constant resemblance, in every part and in different individuals, of the skeletal elements and their disposition.

No separate spicules differing from those already noticed are present; and the tubulation of the spicules is not seen.

A superficial examination of the specimens would lead to the belief of their being Perforata or Tabulata, amongst the Actinozoa and Hydrozoa; but the areolation and structure of the skeleton is not that of the one, nor are there tabulæ or the peculiar hard parts of the other group.

The shape of the skeletal element in the mass is not unlike that of some of the flat *Manons* or *Jereas* of the Cretaceous formation. The arms of the spicules do not bifurcate, however. In the general arrangement of the spicules in the canal-systems there is some resemblance to that in *Turonia*, and there is only a slight one to that of *Aulocopium*, Oswald, which is the only hitherto described Palæozoic organism which resembles the Tetraclade Lithistids. In this form, which is free, hemispherical, and even sometimes spherical, there is a central cavity.

The resemblance is not sufficiently great between the new form and *Aulocopium* to place them together in the same classification; nevertheless there can be no doubt that both

have the general and some of the special characters of those Lithistid Spongida which belong to the Tetracladina.

But the fossilization of the skeletal parts of the new form is not that which is characteristic of mechanical infilling after outgoing of a former mineral—such, for instance, as is seen in calcareous replacement of siliceous spicules. The calcareous mineral of the skeleton is not in distinct crystals, and cleavage-planes are rare; on the contrary, the mineralization resembles that of fossils which were originally of carbonate of lime.

There is a point of some interest which offers some evidence that the original skeleton was not siliceous. In the midst of the long canals, in their interspaces, and passing over the skeletal parts in close proximity are many relics of a large form of *Palæachlya penetrans*, Dunc.; and in sections the passage of the tubes of the parasite through and along the inside of the spicules can be seen. Usually the tube is crammed with the spherical spores; and they frequently extend beyond it and collect in masses. In one instance they crowd a spicule. The tubes and spores are, as in the specimens described in a former number of the 'Quarterly Journal of the Geological Society,' carbonized.

It does not appear to me to be likely that these parasitical plants penetrated after the calcareous fossilization of the interstices was completed; they must be regarded as having grown at the expense of the organic matter of the spicules during the lifetime of the organism. Moreover it must be conceded, from the knowledge we have of the physiology of the *Achlya* group, that it is not probable that they could penetrate and live in silica.

These little spheroidal fossils are, then, of considerable interest; and the more they are critically and carefully examined with all the appliances of the microscope, the more do they resemble the Spongida. Their texture is not that of the perforate coral; and they have no accurate and minute resemblance to the Tabulata; but they are most suggestive from their transitional appearance.

If all the modern Lithistids were siliceous, there must have been a former mimetic and calcareous group of Spongida. Or, as the Lithistids appear to have been rare in the earlier fossiliferous rocks, and *Aulocopium* of the Silurian is the first known, it is possible that a group of Calcareo-Spongida lived contemporaneously and became extinct or merged into a higher form as the parent of Zoantharia Perforata. I have named the fossils, after their discoverer and their shape, *Hindia sphæroidalis*.

Genus Hindia.

The body is free, without an involution of the texture, and consists of a small central space occupied by spicules which soon form a series of bifurcating, long, straight, radiating canals, which open at the surface. The spicule element is calcareous, more or less in the shape of a stemmed tripod, with four limbs, and swollen or fringed at the ends, where junction takes place in the others.

The skeleton is remarkable for its regularity.

Hindia sphæroidalis, mihi.

The sponge-body is spheroidal. On the surface are papilliform eminences corresponding with the ends of canal-spicules. Centrally the spicules are unattached, are tripod-stemmed in shape, with swollen extremities, and have papillose limbs. Canal-system occupying much space; canals straight, narrow, radiating, opening into their neighbours, and formed by combinations of tetraclade spicules resembling those of the central part, and very regular in shape and size.

Locality. Lower Helderberg calcareous shale, New Brunswick.

EXPLANATION OF PLATE IX.

Fig. 1. The figures thus marked are those of separate spicules, showing their three- or four-limbed nature, occasionally expanded ends, and the frequent irregular outline of one or more sides. 1. Solitary spicule from the central space. 1 *a*. A group of united spicules and others whose limbs are not quite in contact, from the outer part of the central space.

Fig. 2. Junction of limb-ends of different spicules (normal). 2 *b*. Junction of limb-end and side. 2 *c*. Expanded ends of limb. 2 *d*. Junction of spicules in part of the canal-system: the frills are shown in two instances in a side view and in one from above. 2 *e*. Junction of the limb-end of a spicule and the side of another.

Fig. 3. The ragged semidenticulate appearance of one of the edges of a spicule-limb. 3 *a*. From the outer part of the central space tangential to some commencing canal-systems: showing the irregular surface of the spicules, and the aborted junction ends.

Fig. 4. The broad spiculate formation of the floor of a canal-system, and a part of a side with included spaces leading to neighbouring canals: this is a longitudinal or radial view. 4 *a*. Tangential section of some canal-systems, not near the surface: they are small systems; and the dark limbs were united in the perfect fossil with other elements. 4 *b*. The reticulation around the canal-openings just beneath an abraded surface. 4 *c*. The nodules on the surface surrounding the openings of the canals or pores, each nodule being a *fourth limb* to a spiculate element.

Fig. 5. Part of a radial section, magnified.

Fig. 6. The body of the fossil, natural size.

Fig. 7. *Palæachlya penetrans*, Dunc., within the skeleton, magnified.