VII. *On Beds of Sponge-remains in the Lower and Upper Greensand of the South of England.*

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[PLATES 40–45.]

IN the course of a search for fossil sponges in the lower cretaceous deposits of the South of England, I have noticed the occurrence at different horizons of beds of rock, of not inconsiderable thickness, composed to a large extent of the spicular remains of sponges. The strata in which these remains occur are well known, and they have been described in numerous papers from the date of Dr. FITTON'S celebrated memoir of "The Strata between the Chalk and Oxford Oolite," in 1827, to the present time, but owing probably to the microscopic dimensions of the remains, and the various changes in their fossilisation which have oftentimes rendered them unrecognisable to ordinary observation, the* organic character of the strata has been seldom recognised, and only in one or two cases have their contents been noticed in detail. The beds have usually been regarded as deposits of sandstone, chert, or siliceo-calcareous materials of an inorganic nature; but though in most cases they contain a varying amount of mechanically derived materials, yet the sponge-remains, and the siliceous deposits derived from their solution, constitute such an important part of their volume as to entitle the beds to be classed as of organic origin, in the same sense as, for example, the upper chalk of this country. In nearly all the outcrops of the lower and upper greensand of the south and south-west of England these sponge-beds are exposed, differing, however, considerably in their development, in the nature of the sponge-remains, and in their condition of fossilisation in different areas, and it is my purpose in this paper to treat (I.), of the general characters of the beds in the various localities; (II.), of the mineral condition of the sponge-remains and of the beds derived from them; and (III.), of the nature of the sponges present in the deposits.

I may premise that the sponge-beds to be referred to, do not, with one or two exceptions, consist of the skeletons of these organisms in a complete or partially complete condition; but they are made up of innumerable multitudes of the detached, minute, microscopic spicules of which the skeletons are composed. The deposits appear to have been produced by the disintegration of the skeletons of numerous generations of sponges, which have successively lived and died in the same areas in

* Mr. J. ARTHUR PHILLIPS mentions the presence of numerous fossils, particularly sponge-spicules, in cherts of lower greensand age. "On the Constitution and History of Grits and Sandstones," Quart. Journ. Geol. Soc., vol. xxxvii., 1881, p. 16.

which the deposits occur. On the death of the animal, the soft tissues by which its skeleton was held together would rapidly decay, and its individual particles would thus become detached from each other and scattered over the surface of the sea-bottom. As a result of this, the fossil sponge-beds consist of a heterogeneous mixture of the skeletal spicules of various kinds of sponges. Under exceptionally favourable conditions of preservation the minute spicules are now met with in a loose, detached condition, not unlike that in which they may be supposed to have been present at the sea-bottom soon after the death of the animal, but, as a general rule, they are now amalgamated with the inorganic materials of the deposits into hard beds of rock, and they have suffered partial or complete solution and replacement by calcite, glauconite, and iron-peroxide.

I. The general Characters of the Sponge-Beds in different Localities.

It is generally known that the principal outcrops of the lower and upper greensand occur round the borders of the Wealden area in the counties of Surrey, Kent, Sussex, and Hampshire. Both divisions are well represented in the Isle of Wight, and, farther westward, the upper greensand is exposed in Dorsetshire, Wiltshire, Somersetshire, and Devonshire. I propose first to refer to the sponge-beds of the lower greensand, and to begin with those on the north-western margin of the Weald, in the county of Surrey.

Haslemere.—In the mostly unconsolidated sands of the district round this town the sponge-beds occur as thin layers of porous siliceous rock of a grayish or yellowish tint. The beds are from one to three inches (·025 to ·075 m.) in thickness. Their exposed surfaces are usually rough and harsh to the touch and uneven. When somewhat weathered the surfaces of the beds exhibit an agglomeration of sponge-spicules, which are thickly intermingled together, without arrangement of any kind. The spicules are cemented together by siliceous material, but the cement is in small proportion to the mass of spicules. The spicules are less clearly shown in the interior of the beds where they are concealed by the matrix, but it is evident from exposed fractured surfaces that the beds throughout are similarly composed of masses of spicules resembling those shown on their upper surfaces, and that there is but a slight admixture of the quartz-sand grains which compose the strata inclosing the sponge-beds. In a sand-pit a short distance to the north-west of Haslemere, a sponge-bed occurs in an unconsolidated condition, and the sponge-spicules are disseminated loosely in the sand, perfectly free from each other. This bed afforded abundant material for the study of the spicules, which are now partly in the state of chalcedony and partly of crystalline quartz. It is a curious circumstance that though loose in the bed, many of the larger spicules have been evenly fractured in three or four places, and the fractured portions have been re-cemented together, sometimes with a slight lateral displacement (Plate 42, figs. 6*a*, *b*).

The sponge-spicules present in these beds are exclusively those of siliceous sponges, and the large majority are acerate and trifid forms belonging to the Tetractinellidæ with a few of lithistid and hexactinellid type.

The exposed sections of the lower greensand round Haslemere are insufficient to determine the extent to which the sponge-beds are developed in it, but fragments of the beds are shown at or near the surface over a considerable district, and they cover the surface of Hindhead and some of the adjoining hills. On the slopes of one of the hills the sponge-beds are extensively worked for road materials. The sandy strata in which they occur have been mapped by the Geological Survey as belonging to the lower or Hythe division of the lower greensand, which is estimated by Mr. TOPLEY* to attain a thickness of about 300 feet in this district. With one or two exceptions the sponge-beds in the lower greensand are limited to the lower division of it.

In a roadside cutting, about half-way between Haslemere and Godalming, sponge-beds are exposed in the form of layers of siliceous and cherty rock which, as presenting a very common type of fossil sponge-beds, may be mentioned in detail. The beds in question consist of a central layer of light or dark translucent chert with an upper and under layer of yellowish, porous siliceous rock. The upper and under crust of rock varies from half an inch to two inches in thickness (·012 to ·05 m.), whilst the central layer of chert is usually of greater thickness; the boundary between the chert and the outer crust is uneven and irregular, and the one kind of rock gradually passes into the other. The outer porous crust consists of a matrix of translucent chalcedonic silica, with, at times, an admixture of quartz-sand and glauconite grains. This matrix is filled with minute cylindrical or fusiform cavities which are the empty moulds of sponge-spicules. In the centre of these cavities there extends occasionally an elongated, very slender, cylindrical siliceous rod, which is really the solidified infilling of the canal of the spicule. Thus, by a peculiar sequence of conditions, the spicules in this portion of the rock have been first imbedded in a siliceous matrix, then their hollow canals have been filled with silica, and finally the spicules themselves have been completely dissolved away, leaving only the casts of their outer form and their solidified canals. In the central layer of massive chert, on the other hand, very frequently the spicules have disappeared; but that it was equally as filled with spicules as the porous crust is shown by the fact that in microscopic sections faint shadowy outlines of the spicules can be detected, and the solidified canals are distinguishable even when other traces of the spicules are wanting. The silica derived from the solution of the spicules of the outer crust appears, in part at least, to have been re-deposited in the central layer in the form of chalcedonic chert, and the spicules of this layer have been thus enveloped by the cherty matrix. As the refractive index of the spicules and of the matrix is similar, the shadowy appearance of their outlines can be accounted for. In some instances there are empty spicular cavities in the chert itself, as well as in the outer crust.

* "The Geology of the Weald." 'Memoirs of the Geological Survey of England and Wales,' 1875, p. 124.

Though sponge-beds are abundant in the Haslemere district I have not met with a single specimen of an entire fossil sponge. The chert beds have been described by Dr. FITTON,* but their organic nature does not appear to have been noticed.

Midhurst and *Petworth, Sussex.*—In the lower greensand strata on the southern side of the Wealden anticlinal, about two and a half miles north of Midhurst, there are exposed several beds of hard siliceous rock, from eight inches to three feet in thickness (·2 to ·9 m.), of a nearly similar character to the sponge-beds near Haslemere. The rock is of a yellowish tint, harsh to the touch and filled with minute cavities. The weathered, broken-up fragments which are plentifully distributed over the fields, clearly show that the beds consist of an aggregate of spicules resembling those in the Haslemere beds. Nearer Midhurst, and at a higher horizon, beds of porous siliceous rock, exhibiting numerous empty casts of spicules, are largely quarried for road materials. These beds consist partly also of sand grains which have been cemented together by the silica derived from the solution of the sponge-spicules, but the spicular casts are sufficiently numerous to show that sponges must have been very abundant. At Midhurst itself there are beds similarly filled with spicular casts and containing also glauconite grains which are cemented by a hard siliceous material. These beds are still higher in the series, and thus the presence of sponge-beds is shown throughout the lower or Hythe division of the lower greensand in this area.

Near Petworth, about five miles east of Midhurst, sponge-beds from four to seven inches in thickness (·1 to ·17 m.), are largely quarried for road material. The beds consist of an outer crust of porous siliceous rock with a central layer of very hard and brittle chert; which, according to Mr. TOPLEY,† bears the local name of whinstone. The chert is filled with spicules, though they are only faintly shown. Both the spicules and the matrix exhibit, under crossed nicols, similar brilliant prismatic tints, indicating that their component silica is now approximately crystalline.

Godalming, Surrey.—On the surfaces of the fields on the summit of the plateau near this town there are frequently present small flat slabs or masses of hard, porous, siliceous rock, from three-quarters of an inch to four inches in thickness. The character of the rock resembles that of the sponge-beds of Haslemere, but the spicules have suffered greater alteration, and they do not weather out so clearly. They can, however, be recognised, not only in casts, but also as delicate white threads intercrossing each other on the weathered surfaces of the beds. Quartz-sand grains, and in some instances a reddish ferruginous material, are also included in the same siliceous cement with the spicules. These rock slabs are evidently portions of a continuous sponge-bed which have remained after the removal of the loose, incoherent sands which constitute the principal part of the strata immediately beneath the surface in this locality.

Tilburstow Hill.—To the south of the village of Godstone, Surrey, the beds of the Hythe division of the lower greensand are well exposed on the north slopes of the

* "Strata below the Chalk." Trans. Geol. Soc., ser. 2, vol. iv., p. 147.

† "Geology of the Weald," p. 125.

ridge known as Tilburstow Hill. They are here largely worked for road material, and, as we have already seen elsewhere, they consist principally of the débris of fossil sponges. To reach the hard beds in the quarries now opened it is necessary to remove the overlying beds of loam, fuller's earth, and dark-green calcareous rock, belonging to the Sandgate division, which are about thirty-eight feet in thickness. Beneath these are beds of siliceous and cherty rock, with thin intermediate layers of sandstone, with glauconite grains and a bed of limestone, in all about eleven feet in thickness (3·3 m.), which are so filled with spicular remains that they may be regarded as a series of sponge-beds. The chert occurs in layers, from 12 to 14 inches in thickness (·3 to ·35 m.), of a lenticular form, and it passes upwards and downwards into the white porous siliceous rock which has been already described as forming an outer crust to it. The sponge-spicules are shown in faint outline in thin microscopic sections of the chert, and the spicular canals, which have been infilled with glauconite, are very distinct. The siliceous matrix inclosing the spicules appears to have been partly deposited in a globular form; it is now either in the condition of chalcedony or of crystalline quartz.

The porous siliceous rock in these sponge-beds is more developed than the chert; there is one layer of it three feet in thickness. Spicular casts are not clearly shown in it, but the silica is of the same character as that in which the moulds of spicules are well preserved, and it also passes into true chert.

The thin intermediate beds of quartz-sand, and glauconite grains, also contain sponge-spicules or their casts, and thus indicate a continuous succession of sponge-life during their deposition.

Besides the chert and the porous siliceous rock, there is in this series a bed of compact grayish-blue limestone, exceedingly hard and tough, filled with sponge-spicules which are now of calcite. This bed is from 12 to 14 inches in thickness (·3 to ·35 m.). A thin microscopic section shows numerous spicules imbedded in a matrix of granular calcite (Plate 40, fig. 4). The spicules are nearly entirely composed of clear, crystalline calcite, but some are of silica; and in many the canals are preserved. Their forms and dimensions clearly prove that they belong to the same siliceous sponges as those of the chert and siliceous beds above and below the layer of limestone, and it is evident that in this latter bed the original silica of the spicules has been nearly entirely dissolved away, and the casts have been refilled with calcite. Exceptionally, an infilling of glauconite takes place instead of calcite. No other organic remains besides the spicules are distinguishable in the limestone.

Dr. Fitton has given a detailed section of these strata at Tilburstow Hill without however noticing the organic nature of the chert. The sections at present exposed vary to some extent from those described in the "Strata below the Chalk."

Nutfield, Surrey.—Beds of gray sandstone, filled with spicules are exposed at this place. A microscopic section of the rock, for which I am indebted to Professor Judd, F.R.S., shows the spicules partly replaced by glauconite and partly dissolved, only their infilled canals remaining. The grains of quartz-sand have been cemented together by the silica derived from the spicules.

Sevenoaks, Kent.—On the summit of the lower greensand plateau a short distance to the south of Sevenoaks, there are beds of chert filled with sponge-remains which are extensively worked for road material. The beds belong to the Hythe division, and according to Mr. TOPLEY* they extend from Brastead Chart to some three miles beyond Sevenoaks Common, and further east the surface of the ground in Great Comp and Malling Woods is also covered with fragments of the same rock.

In a stone quarry near the high road, about a mile from Sevenoaks, the following section was exposed at the time of my visit.

	feet.	inches.
(1.) Chert (sponge-bed)	2	6
(2.) Yellow and reddish sand	2	0
(3.) Chert (sponge-bed)	2	0
(4.) Sand.	1	0
(5.) Chert (sponge-bed)	2	0
(6.) Sand.	0	8
(7.) Chert (sponge-bed) bottom of quarry	1	6
	11	8

The sponge remains appear to be limited to the beds of chert, of which there are four exposed, with a total thickness of eight feet (2·4 m.). The chert is of a gray or light-brown tint, very hard and brittle. In some cases there is an outer crust of light-coloured porous siliceous rock filled with the casts of spicules. In microscopic sections of the chert itself numerous spicules can be seen, embedded in a translucent matrix of chalcedony, which appears to have been deposited concentrically round them. The spicules are also of chalcedony, and their canals are infilled either with silica of a darker tint than the walls or with glauconite. Frequently all traces of the spicular walls have disappeared and only the infilled canals remain, and these might readily be mistaken for perfect spicules. A few small foraminifera and fragments of echinoderms are occasionally present in the chert; with these exceptions it seems to consist of the remains of tetractinellid and lithistid sponges.

In the higher beds of the Hythe division, shown in the railway cutting at the north end of the Sevenoaks tunnel, I did not recognise any well-defined sponge-beds, though in some of the upper beds in the section, both in the so-called hassock and in the rag, the rock is in places filled with casts of spicules.

Fossil sponges are also numerous in beds of loose, unconsolidated, yellowish quartz-sand, belonging to the Folkestone or uppermost division of the lower greensand, of which a section 25 feet in thickness is shown near the Gas Works at

* "Geology of the Weald," p. 119.

Sevenoaks. The sponges here, however, do not occur in definite beds as a rule, but are distributed irregularly through the deposit, in nodular masses of one or more entire sponges enveloped in the sand, which is lightly cemented round them. These sponges are lithistids; but while retaining their complete outer form, their spicular structures have been dissolved, and only casts in a siliceous matrix remain.

A single definite sponge-bed does, however, occur in the deposit, but it is not more than one or two inches in thickness (·025 to ·05 m.). It is made up principally of relatively large acerate and trifid spicules of tetractinellid sponges irregularly mingled together, and with these there are minute skeletal fragments of lithistid, and even of hexactinellid sponges. The spicules are but lightly cemented together with the quartz-sand by a siliceous cement, so that detached forms can be procured by breaking up the softer portions of the bed. The sponges in this deposit were first discovered by Professor PRESTWICH, F.R.S., who very kindly directed my attention to them and conducted me to the beds.

Maidstone, Kent.—There are no very clearly marked sponge-beds in the numerous exposures of the lower greensand near Maidstone. As a general rule sponge-remains are altogether absent in the rag or limestone beds, but in one or two layers of this material near the base of the section in Bensted's quarry, spicules were abundant, but they are now replaced by crystalline calcite or remain as empty moulds. The principal part of the sandstone or so-called hassock-beds, which intervene between the limestone or rag beds, consists of quartz and glauconite grains lightly cemented together by calcareous material, but there are also present other beds somewhat similar in appearance, but with a cementing material of chalcedonic silica, and inclosing lenticular deposits of chert. In these, sponge-remains are abundant, but usually as empty casts. The chert is largely filled with fragments of other organisms as well as sponge-spicules, and the sponges are not so exclusively present as to justify regarding the deposits as sponge-beds. In some of the hassock-beds, however, there are porous siliceous accretions nearly entirely composed of sponge remains, but they are not continuous in a single bed.

On the surface of the fields to the north-west of Maidstone there yet remain numerous slabs or fragments of a hard porous siliceous rock, from one to three inches in thickness (·025 to ·075 m.), in which spicules can be seen. These fragments are very similar to those already described from Godalming, and like them are evidently portions of sponge-beds.

Sponge-spicules appear to have been more abundant in some of the older quarries at Maidstone than they are in those which are now worked, since Sir RICHARD OWEN* mentions that they were sufficiently numerous to be detrimental to the hands of the workmen, and Mr. BENSTED† also states that there were large quantities of them in the lower beds of the series.

* 'Palæontology,' 1861, vol. i., p. 6.

† 'Proceedings of the Geologists' Association,' vol. i., 1859-60, p. 58.

Hythe, Kent.—Sections of about 50 feet in thickness (12·5 m.) of the basal division of the lower greensand are shown in the quarries at the back of the town. The strata consist of alternating beds of limestone, sand, and sandstone, approximately of the same character as those at Maidstone, but less regular as regards the thickness of the beds, and no chert is present. The only traces of sponge remains occur in some of the layers of limestone, and one bed in particular, in the lower part of the section, is so extensively filled with spicules that it may fairly be regarded as a sponge-bed. This bed is about 15 inches (·375 m.) in thickness; it is of a light-gray or bluish tint, hard and massive, except in small patches, where the spicules have been dissolved away and the rock is consequently porous. Thin microscopic sections show that the matrix is granular and the siliceous spicules have been replaced by crystalline calcite. In a few cases the replaced spicules yet show traces of their canals. In addition to the sponge-remains, the bed contains foraminifera and fragments of echinoderms.

The limestone sponge-bed is also shown in a quarry just below the Hythe railway station, and in this quarry there is also a thin shell-bed, principally consisting of the casts of *Trigonia*, in a calcitic matrix. The matrix of this shell-bed is completely filled with the empty casts of sponge-spicules.

Folkestone, Kent.—The uppermost division of the lower greensand, which is named the Folkestone division, from its prominent development in this locality, contains numerous sponge-beds, and in this respect is of a somewhat exceptional character, since sponge remains are of rare occurrence in the strata of this division in other localities.

The best exposure of the Folkestone beds is in the cliffs on the shore between the east side of the Harbour and Copt Point. About half-way between these places the following section was shown at the time of my visit. I here give it in detail, since it illustrates the manner in which the sponge-beds alternate with other beds.

		feet.	inches.
(1.)	Above, coarse sandstone and grit	1	0
(2.)	Brown and yellow sands	6	0
(3.)	Sandstone with spicules	1	0
(4.)	Unconsolidated sand	4	0
(5.)	Siliceous rock (sponge-bed)	1	10
(6.)	Unconsolidated sand	1	8
(7.)	Siliceous rock (sponge-bed)	1	5
(8.)	Sand	1	8
(9.)	Siliceous rock (sponge-bed)	0	5
(10.)	Sand	2	0
(11.)	Siliceous rock (sponge-bed)	1	4
(12.)	Sand	5	0
(13.)	Siliceous rock (sponge-bed)	1	0

		feet.	inches.
(14.)	Sand and siliceous rock	1	6
(15.)	Sand	3	6
(16.)	Siliceous rock (sponge-bed)	0	11
(17.)	Sand	1	0
(18.)	Siliceous rock (sponge-bed)	0	6
(19.)	Sand	1	6
(20.)	Siliceous rock (sponge-bed)	1	0
		38	3

Thus, in this section of 38 feet 3 in. (11·475 m.) there are eight distinct zones or beds of sponge-remains, with a total thickness of 8 feet 5 in. (2·52 m.). These sponge-beds, being of a much harder nature than the intermediate layers of sand, stand out prominently in relief in the face of the cliff, and through the weathering away of the loose sand, large masses and blocks fall down, and are piled over each other on the beach. The sponge-beds consist of spicules in a matrix of coarse grains of quartz-sand and glauconite, cemented by siliceous material. The rock is of a porous or spongiose character, harsh and rough to the touch, and readily friable. There is in some of the beds a central layer of cherty rock, but this is usually porous, though in places it passes into true chert. The spicules in these beds are most clearly shown on weathered surfaces, and they appear to the unaided sight as minute white rods of a dull porcellanic aspect. They are often sufficiently numerous to give a distinct white aspect to the rock surface. In freshly fractured surfaces only empty casts of spicules can, as a rule, be detected. By the aid of a lens, gradual transitions can be detected between apparently perfect spicules and forms with indistinct outlines, in which the spicules are gradually breaking up to form the whitish siliceous cement which binds them and the sand grains into one mass. The cavities in the cherty portions of the sponge-beds are frequently lined with a smooth layer of chalcedonic silica, which shows under the microscope a radiately fibrous structure. When the cavities are infilled by successive layers of this silica, which there can hardly be a doubt is derived from the sponge-spicules, a true chert is produced.

Not infrequently the weathered surfaces of the sponge-beds are covered by a raised network of sub-cylindrical anastomosing branches, resembling the structures generally known as *Spongia paradoxica*. These branching bodies have been mistaken for actual sponges,* but they appear to me to be merely the burrows of marine animals into which the loose sponge spicules have been washed, and from the partial solution of these the burrows have been filled with a strongly cemented material, which resists weathering better than the inclosing rock.

The spicules of these sponge-beds are exclusively of siliceous sponges, and belong

* Mr. F. G. H. PRICE refers to the sponge-beds in this section as seams of coarse calcareous sandstone, and states that large white tabular masses of branching sponge are met with on them. 'Proceedings of the Geologists' Association,' vol. iv., p. 139.

principally to the tetractinellidæ and lithistidæ. I did not find in any of the beds a single example or even the cast of an entire sponge.

The sponge-beds appear not to continue with any regularity in a horizontal direction, and they vary also in their characters in short distances. Thus the beds in the cliff section to the west of the harbour, though only imperfectly shown, are thicker, and decidedly contain more chert than those of the section described. This fact has already been noticed by Dr. FITTON* in the detailed sections which he has given of the various exposures round Folkestone. The same author describes very faithfully the peculiar characters of the sponge-beds, but, strange to say, he does not seem to have noticed the sponge-spicules in them. Mention is indeed made of siliceous spongy or spongiform concretions, but it is clear from the context that reference is only made to the peculiar porous nature of the deposits. They are also compared to the concretionary whetstones in the upper greensand of the Blackdown Hills in Devonshire, which latter, as will be shown in the sequel, are likewise sponge-beds.

Isle of Wight.—Notwithstanding the thickness of the lower greensand strata in the Isle of Wight, sponge-remains do not appear to be present in them.

Faringdon, Berkshire.—Though somewhat beyond the area of which this paper treats, it is desirable to make a brief mention of the remarkable deposit at this place, which has long been known under the name of the "sponge gravel." The character of its deposition, and the nature of the sponges in it are altogether different from those of the beds of the same geological horizon in the Wealden area. It is a thick bed of unconsolidated quartz-sand and pebbles, with numerous sponges and other fossils. Sponges predominate, and they are present in astonishing profusion. They differ from those of the lower greensand of the Wealden area, not only in retaining their complete entire forms, but in the fact that they are exclusively calcisponges. Not a single siliceous sponge has as yet to my knowledge been met with in this gravel, though these calcisponges have been described by various authors as originally siliceous. They thus present a striking contrast to the sponge-beds in other areas, in which the sponges have been entirely disintegrated, and are also exclusively of siliceous origin.

SPONGE-BEDS OF THE UPPER GREENSAND.

Accepting as a typical section that shown in the Undercliff of the Isle of Wight, I propose to include in this term the strata there present between the base of the so-called chloritic marl and the blue micaceous sands, which, in common with Captain IBBETSON† and Mr. PARKINSON,‡ I regard as the upper portion of the gault. Thus

* "Strata below the Chalk," p. 116, *et seq.*

† 'Notes on the Geology and Chemical Composition of the Various Strata in the Isle of Wight,' London, 1849.

‡ Quart. Journ. Geol. Soc., vol. xxxvii., 1881, p. 375.

limited, the upper greensand may be regarded as comprising two broad divisions, an upper, in which beds of chert are largely developed, and a lower, principally consisting of micaceous and quartzitic sands, with occasional layers of chert. The upper division corresponds generally with the zones C and D or Warminster beds of BARROIS,* and the lower with the Blackdown beds or zones B and part of A of the same author. Though these divisions are available for the upper greensand strata of the Isle of Wight, and the outcrops further westwards in the counties of Dorsetshire, Wiltshire, and Devonshire, they are not clearly recognisable in the beds of the same geological horizon to the north and west of the Wealden area. The upper greensand in this area has an altogether different facies; the beds are exposed at intervals in a narrow tract of country, at the base of the chalk escarpment between Godstone in Surrey and Selborne in Hampshire, where they occasionally form a distinct escarpment in advance of that of the chalk. They are known and have been described under the local names of malm, firestone, burrystone, and hearthstone. The peculiar character of these beds arises chiefly from the sponge-remains contained in them, and I propose to describe these before referring to the sponge-beds of the more normal deposits of the upper greensand in the Isle of Wight.

Merstham, Surrey.—There are several exposures of the upper greensand-beds in the escarpment running parallel to that of the chalk, both in road-cuttings and in quarries, the material being extensively employed for building. In a quarry about 1½ mile east of Merstham the following section was shown :—

	ft.	in.		ft.	in.
(1.) Siliceous and siliceo-calcareous rock in thin beds; those near the surface being partially broken up	4	0	to	5	0
(2.) Bed of same rock as No. 1, but in large compressed nodules which in places decompose to a reddish clay				0	8
(3.) Bed of siliceo-calcareous rock. Firestone or malm . .				10	0
				15	8

In an adjoining roadside cutting, where, however, the beds are not so distinctly shown as in the quarry, the bed marked 1 is overlaid by a layer of soft glauconitic marl, which is probably the equivalent of the chloritic marl.

The rocks of the above section are, when fresh, of a light brown tint and earthy aspect; they become white or grayish-white when dry, and are then considerably harder. The rock is minutely porous and largely absorbent of water, and when dry, of light specific gravity. It is soft to the touch and not adherent to the tongue. In some places the light brown rock gradually passes into one which is heavier, more compact, and of a light-bluish tint, and frequently becomes nodular. These nodules are locally known as flints, but they have an altogether different appearance to the

* 'Recherches sur le terrain crétacé supérieur de l'Angleterre et de l'Irlande,' p. 106.

normal flints of the upper chalk. There are also pockets of a reddish-yellow loamy clay which appear to be produced by an alteration of the normal rock. Some portions of the beds do not appear to contain calcareous material, in others calcite is present and the rock is then harder and denser. When a fractured surface is examined with a strong hand-lens it is seen to consist of minute silvery mica-scales, points and rods of glauconite, and white powdery siliceous granules. Fragments of sponge-spicules are also visible, but these are less numerous than the minute hollow cavities of spicules with which the rock is throughout interpenetrated, and to which it owes its porosity. These spicular casts are very minute, and it requires careful observation to detect them (Plate 40, fig. 7).

Thin sections of the harder portions of this rock, examined under the microscope, still further confirm its organic origin and its derivation from the spicules of siliceous sponges. The sections show spicules, mostly fragmentary, irregularly distributed in the siliceous and siliceo-calcareous matrix. The points and rods of glauconite can be recognised as portions of siliceous spicules replaced by this mineral. The spicules which yet remain siliceous are white by reflected, and transparent by transmitted light; they are negative to polarised light, and thus show that the silica still retains the amorphous colloid condition in which it is present in recent siliceous sponges. The silica of the matrix, and also that infilling the empty casts of the spicules, is partly in the form of minute discs or globules (the character of which is more fully referred to in the sequel), likewise of amorphous silica, and partly of transparent chalcedonic silica (Plate 40, fig. 5).

In the general mass of the rock, the spicules which yet remain intact are firmly imbedded in the siliceous matrix, but in the decomposed clayey portions some may be obtained by washing, free from matrix. They are principally acerate and trifid spicules belonging to tetractinellid sponges, mingled with others of lithistid and hexactinellid types. There is a general resemblance to the spicules of the sponge-beds from the lower greensand, and to those from the upper greensand of the Isle of Wight and the South-Western counties, but at the same time they are notably of smaller dimensions. Not only in this locality but generally in the beds of malm or firestone to the north and west of the Weald the same minute forms occur.

The spicular constituents of this rock are not shown with equal clearness in every portion of the beds exposed, but, as the nature of the rock is similar throughout, there is reason to suppose that it is all of similar origin, and may be regarded as a sponge-bed. I could not determine whether the quarry-section referred to, 15 feet 8 inches in thickness (4·7 m.), embraces the total* thickness of the malm at this place.

Notwithstanding the abundance of the detached spicules I did not meet with a single entire sponge or even a fragment of one in this bed; they all appear to have

* Mr. Topley, in the "Geology of the Weald," p. 154, states that the total thickness of the upper greensand at this place is 22 feet, but this includes the bed of chloritic marl; Dr. Fitton, in the "Strata below the Chalk," p. 140, places the total thickness at 25 feet, but he did not himself see the section.

been disintegrated and reduced to their individual elements. The organic nature of the rock does not appear to have been previously noticed.

Godstone, Surrey.—About three miles east of the quarries at Merstham, beds of the same age are worked by the side of the high road north of the village of Godstone. There is here an upper bed of soft rock 5 feet 8 inches in thickness (1·36 m.), which is largely quarried for hearthstones. This rock is of a more friable character, and contains more calcite than the malm or firestone; but empty spicular casts and spicules replaced by glauconite are present in it, and the silica is also in the amorphous globular form. Beneath the hearthstone-bed there are beds 14 feet in thickness of malm or firestone, of a similar character to those at Merstham, and similarly filled with sponge-remains. In these there are at intervals parallel layers of the hard blue nodular aggregations known as flints, which are from 3 to 4 inches (·075 to ·1 m.) in diameter. These nodules are not sharply delimitated from the inclosing rock, in the same manner as the flints in the chalk, but there is a gradual passage from one to the other. They are disposed, however, in definite planes of bedding in the same manner as the chalk-flints. The sponge-spicules are much more distinctly shown in these blue nodules than in the white portion of the rock. A magnified section of one of these nodules is shown on Plate 40, fig. 2.

Reigate and Betchworth, Surrey.—A short distance to the west of Reigate and again about two miles further west, close to Betchworth station, quarries are opened to obtain the hearthstones and firestones. In the upper beds of the quarries the base of the chalk marl is shown, and beneath this a bed from 4 feet to 8 feet in thickness of a soft greensand in which glauconite grains are very abundant. This bed represents the chloritic marl. The hearthstones are here 10 feet in thickness (3 m.) and the firestone beds beneath are of an equal thickness. The character of these rocks closely resembles that of the beds at Merstham and Godstone.

Farnham, Surrey.—The upper greensand strata near this town were formerly largely worked for agricultural purposes and for building, but good sections are no longer exposed. According to Messrs. WAY and PAINE,* who have given a detailed description of the beds, they have a total thickness of over 60 feet, of which the upper 40 feet (12 m.) is a soft friable rock, known as malm or soft Surrey sandstone, and the lower 20 feet (6 m.) is of a harder character, and is called firestone.

The malm rock is of a creamy-white tint, and very soft and porous, and of relatively light gravity when dried. With the exception of a few mica-scales and particles of glauconite it appears to be entirely siliceous. Its friable character does not permit microscopic sections to be made from it, but reduced to powder and examined in Canada balsam, fragmentary spicules both of silica and of glauconite can be seen in it. The greater part of the silica in the rock is in the globular form, and the minute globules or discs occur detached in the powdered material (Plate 45, figs. 18–18*b*). This globular silica, as well as that of the spicules, is in the amorphous condition and

* 'Journal of the Royal Agricultural Society,' vol. xiv., 1853, p. 232, *et seq.*

it is entirely negative between crossed nicols. The empty spicular cavities, to which the porous nature of the rock is due, appear in fractured surfaces as very minute, short, straight tubes or open canals from ·15 to ·4 mm. in length by ·03 mm. in width. They are undoubtedly the casts of acerate and trifid siliceous spicules, and they are sufficiently numerous to show that the silica derived from the solution of the contained spicules can have produced the colloid material of which the rock principally consists. There can be no doubt that this malm rock is derived from the spicules of siliceous sponges.

Messrs. WAY and PAINE first called attention to the fact that the Farnham malm and firestone contain a large amount, varying from 25 to 75 per cent., of soluble silica, but they do not appear to have noticed the peculiar globular form in which the silica has been deposited, and* they deny its organic origin.

Selborne, Hampshire.— The malm rock is well shown in the quarries at this village, where a section of 15 feet (4·5 m.) is exposed; also in road-cuttings and on the surfaces of the adjoining fields. It is of a much harder and more compact character than that at Farnham, and contains a fair proportion of calcite, which renders it more suitable as building material. Spicules and spicular casts abound in it. Some of the casts of spicules in the more calcareous beds have been refilled with crystalline calcite, whilst in sections of the more siliceous beds the spicules are seen thickly grouped together, surrounded by globular silica and also by transparent chalcedonic silica. The spicular canals are infilled by glauconite, which remains intact after the spicular walls have been dissolved.

GILBERT WHITE, in the 'Natural History† of Selborne,' referring to this rock, states that it is but little removed from chalk in appearance, but seems so far from being calcareous that it endures extreme heat. It was known as the white malm, in contradistinction to the chloritic marl, which was called the black malm. Its organic origin does not seem to have been suspected.

Wallingford, Berkshire.—The malm rock is not limited to the northern margin of the Weald, for at Wallingford, which is situated about thirty-two miles to the north-west, there are exposed beds of siliceo-calcareous rock of the same character as those already described round the Wealden area. The rock is hard, and calcite is only occasionally present in it, but there is a greater relative amount of quartz-sand and other mechanically derived constituents than in the malm of the Wealden district. The sponge-remains are either as empty casts or of amorphous silica, and the siliceous matrix is partly in the globular form.

* "On the Silica Strata of the Lower Chalk." 'Journal of the Royal Agricultural Society,' vol. xiv., p. 243. These authors state that it is "not infusorial, for with the exception of a few foraminifera no traces of animal life can be observed in the rock by microscopical examination." They attribute its formation to "aqueous decomposition resulting from the contact of silicate of lime in solution, derived from the older rocks, with carbonic acid, produced either by vegetable and animal decay or by volcanic agency, so that at one and the same time carbonate of lime and gelatinous or soluble silica would be formed."

† BELL'S edition, p. 3.

Eastbourne and Folkestone.—According to the Geological Survey Memoir,* the characteristic malm does not extend round the south-western margin of the Weald, but gradually disappears to the east of Steyning, in Sussex, and the upper greensand is represented by beds of sandy marl which extend as far as Eastbourne. In these beds I have not discovered any sponge-remains, but in some higher beds of dark grayish glauconitic sandstones, belonging to the horizon of the chloritic marl or the base of the chalk marl, there is a very characteristic sponge-fauna, which differs so greatly from that of the upper greensand proper that it merits notice, although beyond the limit assigned to my paper. These sponge-beds, or reefs, as they are termed by Mr. PRICE,† appear to consist exclusively of entire examples of hexactinellid sponges belonging to the genera *Plocoscyphia*, *Craticularia*, and *Stauronema*, growing together in such abundance that the exposed rock surface is covered with them. These and similar sponges are either wholly absent from the sponge-beds of the lower and upper greensand or represented by mere microscopic fragments of their skeletal mesh, and their presence in these deposits may be regarded as indicating the existence of different conditions, in which deeper water prevailed than when the greensand sponge-beds were formed.

Shanklin, *Ventnor*, and the *Undercliff*, *Isle of Wight*.—The sponge-beds in the upper greensand of these places principally occur in the upper division, characterised by bands of chert and siliceo-calcareous rock. The beds are well shown in the quarries near Shanklin and at Ventnor, and along the Undercliff. The striking parallel bands of cherty rock which project in relief in the upper portion of the cliff, and the huge masses of the same material scattered over the terraces beneath, consist of sponge-beds. At the Railway Station at Ventnor the following section is exposed; the bed marked 1 is immediately overlaid by the chloritic marl.

	feet.	inches.
(1.) Siliceo-calcareous rock, with bands of chert (sponge-bed)	21	0
(2.) Siliceo-calcareous rock	4	0
(3.) Building stone with nodular layer of bluish limestone	1	7
(4.) Freestone of quartz-sand, glauconite, and mica cemented by calcite	3	2
(5.) Freestone, similar to above, but with some silica in cementing material	4	10
(6.) Beds of siliceo-calcareous nodules with chert	1	4
(7.) Freestone of similar character to bed 5	4	9
(8.) Hard siliceo-calcareous rock, with chert	1	0
(9.) Freestone resembling bed 5	3	0
(10.) Freestone and chert to base of quarry	3	0
	47	8 (=14·3 m.)

* "Geology of the Weald," p. 158.

† Quart. Journ. Geol. Soc., vol. xxxiii., p. 435.

The upper layers (21 feet in thickness) of this section so abound with spicules that they may be considered as a continuous sponge-bed. The chert resembles that which has already been described from the lower greensand. It is usually of a light brown tint, and in thin sections under the microscope it is seen to be filled with spicules and spicular casts imbedded in a translucent matrix of chalcedonic silica. The spicules are likewise of chalcedony, and their canals are infilled with glauconite. Another variety of chert, also very abundant, is of a grayish or greenish-white tint; it differs from the former in that the matrix is of amorphous silica, whilst the inclosed spicules are of chalcedony. The chert bands here, similar to those of the lower greensand, are enveloped in an outer crust, of varying thickness, of white or yellow siliceous porous rock, which is interpenetrated with the empty moulds of spicules.

In some of the thicker masses of chert there are cavities or pockets filled with spicules, loosely mingled in a grayish siliceo-calcareous powder, in which there are also numerous well-preserved foraminifera, chiefly of the genus *Textularia*. The spicules in these cavities have undergone a remarkable alteration in structure; they appear to have lost their original silica, which has been replaced by glauconite and some other silicate of a greenish-white aspect. The replacing material has only partially filled the form of the original spicules, and thus they look like mere shadowy casts of complete spicules. These in many cases are peculiarly distorted and contracted (Plate 45, figs. 15*a*—*e*).

Spicules in varying quantities are also present in the beds of freestone and other siliceo-calcareous layers, in all about 27 feet in thickness, which form the lower part of the section at the Ventnor Station quarry. These beds consist principally of fine grains of quartz and glauconite with mica and calcite, and in appearance they resemble the malm rock of the northern margin of the Weald, and, in fact, they have thus been named by Mr. PARKINSON.* They differ, however, from the true malm in the small proportion of silica which they contain, and I have not seen in them any silica of the globular form so common in the malm. The sponge-spicules in these beds are mostly represented by their hollow moulds, and these are so minute that only by careful scrutiny can they be detected. They are, as a rule, more readily recognisable in the small dark phosphatic nodules which frequently occur in the beds. The spicules are not sufficiently abundant, however, for these beds to be considered as definite sponge-beds.

In the lower series of the upper greensand strata, consisting of about 50 feet (10·5 m.) of yellowish-gray micaceous sands, usually soft and unconsolidated, but with occasional harder bands, I did not detect any well-defined sponge-beds, but spicules are fairly abundant in some of the layers, and it is not improbable that a careful search would show their presence throughout.

The sponge-beds of the Isle of Wight, like those of the lower greensand, exclusively consist of the detached spicules of siliceous sponges. A few entire lithistid sponges

* Quart. Journ. Geol. Soc., vol. xxxviii., p. 370.

of the genus *Jerea* are occasionally met with, but the exact horizon in which they occur is not known, though I should judge from the character of the rock containing them that they belong to the horizon of the freestone beds.*

Warminster, Wiltshire.—From the upper greensand strata of this locality entire forms of lithistid sponges have been met with in one or two limited areas, but they are of comparatively rare occurrence, and appear to be seldom found at the present time. On the other hand, beds of rock filled with the detached spicules of lithistid and tetractinellid sponges are exposed at Warminster itself, and in other places south of it, to beyond the village of Crockerton. The sponge-beds are largely worked for road material, and fragments of them are abundant on the surfaces of the fields, under which the beds crop out.

The following section is shown in a quarry on the outskirts of Warminster :—

	feet.	inches.
(1.) Broken fragmentary chert in a marly matrix . . .	3	0
(2.) Greensand of quartz and glauconite grains . . .	1	0
(3.) Chert (sponge-bed)	1	0
(4.) Greensand similar to bed 2	1	0
(5.) Siliceo-calcareous rock and chert, partly decomposed to a reddish loam (sponge-bed)	2	3
(6.) Greensand similar to bed 2	1	3
(7.) Siliceous rock with chert (sponge-bed)	2	6
(8.) Greensand	1	0
(9.) Siliceous rock with chert (sponge-bed) to bottom of quarry	1	3
	14	3 (=4·275 m.)

Near Chute Farm, about four miles south of Warminster, another section is exposed as follows :—

	feet. feet.	inch.
(1.) Broken chert and siliceous rock	1 to 2	0
(2.) Siliceo-calcareous rock and chert in beds of varying hardness (sponge-bed)	10	0
	12	0 (=3·6 m.)

* I noticed large masses of rock with some of these sponges weathered out on their surfaces on the beach about two miles west of Ventnor. From their appearance I could understand the origin of the remarkable figures of the tulip alcyonium given by Webster in 'Transactions of the Geological Society,' 1814, vol. ii., p. 377, pl. 28. One need hardly say that the enormously long stems which are there represented as portions of the sponge have no real connection with it. These supposititious stems have been based on long cylindrical tubes with fluted walls, which interpenetrate the rock. Whatever may be the true nature of these tubes it is certain that they are not the stems of sponges.

The siliceo-calcareous rock of which the sponge-beds are largely composed is of a whitish appearance, and consists of silica, both amorphous and as chalcedony, calcite, a small quantity of mica, and grains of glauconite and quartz. It is filled with spicules of relatively large size; they are now of a porcelanic white by reflected light, and transparent in Canada balsam by transmitted light; they are usually perfect, and their canals are well-preserved. These spicules are of amorphous silica and are entirely negative between crossed nicols, though their canals are usually infilled with chalcedonic silica or with glauconite, and the transparent siliceous matrix in which they are imbedded is also chalcedonic. The spicules are in such profusion in some of the beds that they form distinctly-marked thin white parallel layers with intermediate layers, which, from the larger proportion of glauconite grains in them, are of a greenish tint. These parallel layers must have been thus arranged at the time the beds were forming, and they indicate the disintegration of the sponges and the mingling of their spicules before they were buried under fresh deposits. The perfect condition of the spicules likewise indicates that they could not have been drifted to any extent over the sea-bottom (Plate 40, fig. 1).

The white siliceous rock filled with spicules occasionally passes into a brown chert; in this rock the spicules are to a large extent dissolved away, and only their infilled canals and shadowy casts remain. It is evident that the cherty portions were originally as filled with perfect spicules as the siliceous rock into which they gradually pass, and the difference results from the solution of the amorphous silica of the walls of the spicules, and its re-deposition in the chalcedonic condition to form the chert.

In some of the sponge-beds there are cavities or pockets in the chert filled with a loose, powdery, unconsolidated material, of the same character as that already mentioned in the chert at Ventnor. The spicules in this material are, however, for the most part, in a perfect condition, and can be washed perfectly free from the matrix; but others have undergone a similar alteration to that of the Ventnor spicules, and they have been partially replaced by a nearly transparent mineral, and the silica is in the globular form (Plate 45, figs. 15, 16). Much of the silica in the powder of these cavities is in the form of minute globules or discs, and the silica is amorphous (Plate 45, figs. 19–19*e*).

Penzlewood, Somerset.—On the plateau formed by the summit beds of the upper greensand at this place, and at the adjoining villages of Stourton and Zeals, in Wiltshire, there are exposed beds of chert and siliceous rock, which are estimated by Mr. HORACE B. WOODWARD* to be from 20 to 30 feet in thickness. The beds are largely worked for road material, and they have been formerly extensively employed for building and also for the manufacture of whetstones† for sharpening

* "Geology of East Somerset." 'Memoirs of the Geological Survey,' p. 138.

† My attention was first directed to these beds, by my friend Mr. ALFRED GILLETT, of Street, who showed me one of the whetstones made at this place. A fractured surface at once showed that the hard, porous siliceous rock, of which it was made, was a portion of a sponge-bed, since it was filled throughout with the empty casts of siliceous spicules.

scythes. The chert in these beds is of the same character as that which has been already described from Ventnor and elsewhere. Spicules are abundant in it, but their walls are frequently dissolved, and they are now largely represented by their infilled canals (Plate 40, fig. 3). This chert is accompanied, and frequently inclosed, by the hard, harsh, porous siliceous rock filled with spicular cavities so generally present. In some places this description of rock has been naturally broken up, so as to form beds, five or six feet in thickness, of small irregular fragments having a pumice-like aspect.

In addition to the chert and porous siliceous rock, some of the sponge-beds in this district consist of a hard, whitish, massive rock, of a granular character, filled with spicules of a white porcelanic tint. The rock appears to be nearly entirely siliceous, the silica is partly chalcedonic and partly amorphous, and in the globular form. The spicules are of amorphous silica, similar to those at Warminster. Small cavities in this rock are filled with spicules partially cemented together.

The sponge-beds of this locality are distinguished by the absence of calcite and the small proportion of glauconite and mica present in them. Their organic character does not appear to have been hitherto noticed, although they have excited much attention, owing to the fact that over an extensive area numerous conical pits have been made in them to extract the harder portion of the beds for economical purposes, and these pits have been surmised to be the* remains of primitive dwellings.

Blackdown Hills, Devonshire.—The beds of upper greensand age exposed in the higher portion of the Blackdown Hills have formed the subject of numerous memoirs, in which some reference is made to the occurrence in them of sponge-remains. The detached spicules met with here and at Haldon were first described and figured by Mr. E. PARFITT,† and later in a more complete manner by Mr. H. J. CARTER, F.R.S.,‡ but these authors do not describe in detail the beds in which they occur. The beds have formerly been extensively worked for whetstones and for building, and Dr. FITTON § gives full details of the beds employed, and the mode of manufacture of the whetstones, without, however, noticing their organic character.

The basal beds of the greensand consist of a fine-grained yellowish sand-rock, which, according to Mr. DOWNES,|| is 30 feet (9 m.) in thickness. This is overlaid by a series of beds of sand and siliceous rock varying from 12 to 20 feet (3·6 to 6 m.) in thickness, which contain the so-called concretions used for whetstones. These are of a greenish tint when moist, and gray when dry. The rock is porous, very harsh to the feel,

* 'Proceedings of the Somerset Archæological and Natural History Society,' vol. xv.; also "Remarks on the Pen Pits and other supposed Early British Dwellings." By H. B. WOODWARD, in the 'Midland Naturalist,' 1883.

† 'Transactions of the Devonshire Association for the Advancement of Science, 1870.'

‡ Ann. Mag. Nat. Hist., s. 4, vol. vii., 1871, p. 112.

§ "Strata below the Chalk," p. 236.

|| Quart. Journ. Geol. Soc., vol. xxxviii., p. 80.

partly hard, and partly soft and friable. It is filled with sponge-spicules and their empty casts, cemented together by chalcedonic silica. Quartz-sand and glauconite grains are also present, but no calcite, and only a small amount of mica. In the softer portions the spicules are so lightly cemented with the other materials that by gently breaking up the accretionary masses they may be obtained in great numbers and with their forms perfect. The spicules are chiefly of chalcedonic silica; some appear to be partly of crystalline silica; they are nearly transparent in Canada balsam, and require to be mounted for the microscope in glycerine. Spicules are abundant also in the unconsolidated sand of the whetstone series of beds, and they may be regarded as filled with sponge-remains throughout, and forming a continuous sponge-bed. The cementing silica, which renders this material suitable for whetstones, is derived from the solution of the spicules, and the chalcedonic silica, which has replaced the calcite of the molluscan shells in the same beds, may be attributed to the same source.

Above the whetstone series of sponge-beds, there are beds of sand and sandstone (beds 10, 11, of Mr. DOWNES), and these are again succeeded by sands with siliceous rock and chert, which are also composed of sponge-remains. On the summit of Blackdown, near Cullompton, there are beds of cherty débris 5 to 10 feet in thickness, imbedded in a clayey matrix. Though much weathered, spicules can yet be recognised in some of the masses of chert, and it seems to me highly probable that these beds of débris represent the chert series or sponge-beds, which at Warminster, Penzlewood, and at Ventnor, form the summit of the upper greensand.

Though detached spicules are so abundant, entire sponges are now comparatively rare in the Blackdown beds. The well-known *Siphonia pyriformis* (*S. tulipa*, ZITTEL), figured by SOWERBY* in Dr. FITTON's memoir, is stated by Mr. DOWNES† to be limited to a single layer, and the spicules of this species very seldom occur in the sponge-beds, which are principally composed of the acerate and trifid forms belonging to tetractinellid sponges and of the large spicules of megamorine lithistids.

Haldon Hills, Devonshire.—The upper portion of these hills, like those at Blackdown, about twenty miles to the north-east, consists of beds of upper greensand age. A section of about 30 feet (8·7 m.) of strata is exposed by the side of the high road between Exeter and Dawlish. The beds are principally of quartzitic and glauconitic sands, with nodules and bands of chert. The sponge-remains principally occur in a layer of chert from 8 inches to 1 foot in thickness, and in a bed of reddish-brown quartz-sand, 10 feet in thickness, at the base of the section. The sand is unconsolidated, and it is in places filled with detached sponge-spicules, which can be obtained quite free from the matrix. The spicules are for the most part similar in form to those at Blackdown, but they are not so well preserved. The silica of these spicules is partly crystalline and partly chalcedonic.

Axmouth, Beer Head, Devonshire.—I have not had an opportunity of examining

* "Strata below the Chalk," 'Geological Transactions,' 2 ser., vol. iv., p. 340, pl. 15*a*.

† Quart. Journ. Geol. Soc., vol. xxxviii., p. 81.

the sections of the upper greensand at these places, but according to Mr. C. J. A. MËYER,* there is one bed (No. 6) of a light-coloured sand, with chert in nodules or layers, varying from 7 to 25 feet (2·1 to 7·5 m.) in thickness, which is crowded with sponge-spicules. Dr. BARROIS† places this bed on the same geological horizon as the Blackdown deposits, but Mr. MËYER believes it to be above these latter.

Sponge-beds in deposits of corresponding age in Germany, France, and Belgium.

The general distribution of beds of sponge-remains in the lower and upper greensands of the south of England would of itself furnish a strong probability that similar beds might also occur in the same formations on the Continent. This has already been shown to be the case with respect to the Hils-sandstein in Westphalia, and I am enabled to bring forward some evidence of the presence of sponge-beds in strata of cenomanian age in France and Belgium.

Hils-sandstein, Westphalia.—This formation, which has a thickness of 150 m. (492 feet), was, until 1879, believed to be an ordinary sandstone composed of quartz-sand and mica cemented by silica. It was then stated by Herr WŒCKENER ‡ to be largely composed of huge sponges of irregular form, but Professor ZITTEL § showed that the supposed sponges were in reality nodular masses of rock filled with sponge-spicules or their casts, and that this rock was of organic origin and filled with the remains of sponges which lived on a sandy sea-bottom. The character of the rock very closely resembles the sponge-beds of Haslemere, and the formation is on the same geological horizon as the lower greensand.

France and Belgium.—The description given by Dr. CHARLES BARROIS‖ of the petrological characters of the so-called gaize de l'Argonne corresponded so exactly with the characters of the sponge-beds in the upper greensand that, in default of an opportunity of seeing this rock *in situ*, I applied to Dr. BARROIS to furnish me with hand-specimens of it. My request was most kindly complied with, and the specimens which Dr. BARROIS supplied to me from different localities fully confirmed the anticipations which I had formed that the gaize was of organic origin, and largely composed of the remains of sponges. The specimens were obtained from the following localities, and I append short descriptions of their characters :—

(1.) *Grand Pré, Ardennes.*—The gaize is a gray or grayish-yellow rock with bluish spots, soft to the feel, friable, and very porous. It appears to be principally of amor-

* Quart. Journ. Geol. Soc., vol. xxx., 1874, p. 373.

† 'Recherches sur le terrain crétacé de l'Angleterre,' p. 70.

‡ 'Zeitschrift der deutschen geologischen Gesellschaft,' vol. xxxi., 1879, p. 663.

§ *Id.*, p. 786.

‖ 'Annales de la Société Géologique du Nord,' tome v., 1877–78, p. 153. The author says, "Cette gaize est une roche tendre, légère, argileuse et silicieuse, très poreuse; elle se délite à l'air avec la plus grande facilité; sa couleur est grise; elle contient cinquante pour cent de silice gélatineuse."

phous silica in minute granules; there are also grains of quartz-sand, minute scales of mica, and some glauconite. The rock is interpenetrated throughout with the empty casts of spicules, which give to it its porosity and lightness. A few of the spicules themselves also remain, and these are of amorphous silica, like the matrix. The specimen is a typical example of a fossil sponge-bed. Its characters correspond closely with the upper greensand malm of Merstham, but the gaize contains no calcite, and the silica, though amorphous, is not redeposited in the globular form. How far the specimen sent me may represent the general characters of the gaize de l'Argonne, which is stated to be 100 mètres (328 feet) in thickness, I am unable to determine, but if it is a fair sample of this deposit, it forms an immense bed of sponge-remains, which far exceeds in thickness those present in the greensands of this country.

(2.) *Montblainville, Meuse.*—The specimens of gaize are soft, minutely porous, of a bluish-gray tint, with yellowish-gray bands, which appear to be the remains of entire sponges, now decomposed beyond recognition. The rock is largely of amorphous silica, entirely negative to polarised light, and it is partly present in the globular form. The globules or discs are of the same transparent hyaline character as those from Farnham, but the majority of them are smaller; they are from ·006 to ·02 mm. in diameter. In addition to the remains of entire sponges, the matrix is filled with the minute casts of detached spicules as well as some of the spicules themselves. The silica of these is amorphous, and appears to be assuming the globular form, like that of the matrix. A further peculiarity of these spicules is that the concentric layers of silica composing their walls can be detected under the microscope. The specimens are from a true sponge-bed.

(3.) *Bracquegnies.*—Meule (gaize) zone *à Ammonites inflatus.*—The specimens of this rock are extremely light, porous, and friable. The rock is rough to the feel, of a greenish-white tint, with numerous green specks in it; it has generally the aspect of pumice. Its structure resembles that of the gaize from Grand Pré. The silica is largely amorphous, occasionally in the globular form, but usually in minute irregular particles. It is throughout filled with spicules and empty spicular casts. According to* M. M. Briart and Cornet, this meule de Bracquegnies contains large quantities of soluble silica, as well as silica in the form of chalcedony, and judging from the specimen forwarded to me by Dr. Barrois, this silica has been derived from the solution of the siliceous sponge-spicules with which the rock was filled. The able authors above mentioned have very fully described the larger fossils in the meule, which appear to be on the same geological horizon as the Blackdown sponge-beds, but they do not seem to have noticed the sponge-remains to which the deposit owes its principal mineralogical characters.

(4.) *Rumigny, Ardennes.*—Gaize (albien).—Thisrock is hard, of a greenish-gray tint, from the coarse glauconite grains with which it is filled. The silica which

* 'L'Académie Royale des Sciences, &c., de Belgique,' tome xxxiv., 1867—70.

cements the particles is partly amorphous and partly chalcedonic. It contains spicules and fragments of lithistid and hexactinellid sponges, but not sufficiently numerous to be deemed a sponge-bed.

(5.) *Chaumont de Porcion, Ardennes.*—Marne de Givron.—This rock, which occurs at a slightly higher horizon than the gaize, is of a grayish tint and soft structure. It consists largely of calcite, with glauconite, and a small quantity of colloid silica in the globular form. There are fragments of entire sponges in it, as well as traces of detached spicules, but these do not bear sufficient proportion to the other materials to constitute it a sponge-bed. In another specimen of the same rock, from Givron itself, the sponges have been replaced by iron peroxide, like those of the lower and upper chalk of this country.

II. Mineral Conditions of the Sponge-Remains and of the Beds derived from them.

With the single exception of the sponges in the lower greensand strata at Faringdon, which are calcisponges, the spicular remains forming the sponge-beds above referred to, both from the lower and upper greensand, are exclusively those of siliceous sponges. These spicular remains resemble so closely those of existing siliceous sponges, that the silica of which they are formed may be assumed to have been originally in the same colloid, hydrated condition in which it is present in the skeleton of recent forms. But no fossil sponge is yet known in which the spicular skeleton retains that transparent hyaline condition which is so striking a feature of recent siliceous sponges; the silica, in all, has undergone various molecular alterations, and now presents numerous gradations between the amorphous or colloid and the crystalline state. Further, the changes in the fossil sponges have not been limited to alterations in the condition of the silica merely, but the silica itself has frequently been partially or entirely dissolved and replaced by calcite, glauconite, and other minerals, or removed, leaving the empty cast of the spicule. These modifications of the fossil sponge skeleton were first made known by Zittel and Sollas, and though at first regarded with doubt, on account of the supposed stability of silica, are now generally recognised. The investigations of *Mr. Hannay, and those of M. Thoulet,† have proved that the silica of recent sponges is readily susceptible to the influences of the chemical ingredients of sea-water, and has a strong tendency to dissolution after the death of the animal, so that the changes in the silica of the fossil spicules are only such as may have been anticipated.

To a great extent the accumulated masses of detached spicules in the sponge-beds present the same modifications arising from fossilisation as those of entire sponges, which have hitherto been mostly studied, but in the sponge-beds we have also to take

* 'Memoirs of the Literary and Philosophical Society of Manchester,' vol. vi., 3 s., p. 234.

† 'Bulletin de la Société minéralogique de France,' tome vii., 1884, p. 147.

into consideration the mineral characters of the deposits in which the sponge-remains are imbedded, which in many cases are derived from the spicular remains themselves.

The detached spicules of the sponge-beds are now in the following mineral conditions :—

I. Silica; either in the amorphous or colloid state; or crypto-crystalline like chalcedony; or crystalline.

II. Glauconite and other silicates.

III. Crystalline calcite.

The beds or matrix inclosing the spicules, in addition to such mechanically derived constituents as quartz-sand, mica, and grains of glauconite, also contain silica in the same forms as in the spicules, and calcite, either granular or crystalline. The calcite is probably of organic origin, and derived from the remains of foraminifera and other organisms.

IV. The spicules also occur in the negative form, in which the silica has been entirely removed, and the casts are either empty, or merely contain the solidified canal of the spicule.

As the mineral characters of the spicular remains, and of the beds in which they are inclosed are, to a great extent, interdependent, it is more convenient to consider them in connection with each other.

I. *Spicules and matrix of colloid silica.*—The spicules which yet retain the silica in the amorphous condition are, as a rule, more perfectly preserved than those in which the silica is partially crystalline; their surfaces are smooth and even, and their canals are distinctly shown. They are of a milky-white or opal tint by reflected light, and, when mounted in Canada balsam are nearly transparent. Between crossed nicols, the spicular walls are entirely neutral, though the canals, which are frequently infilled with chalcedonic silica, are doubly refracting. Viewed by transmitted light the spicular walls can be seen to be traversed in all directions by very minute curved lines (Plate 40, fig. 8), which, under high powers, are resolved into incomplete elliptical rings, with smooth even rims (Plate 40, fig. 9). Besides this tendency to circular aggregation, the silica of the spicules frequently exists as very minute granules of irregular forms, showing by transmitted light a decided pinkish tint. In no instance does the spicular canal exist as a hollow tube, but it has been filled either with silica, glauconite, or other silicate, or, rarely, with a ferrous compound. The infilling material is generally of a more resistant nature than the walls of the spicules, so that the walls are frequently entirely dissolved, whilst the materials which have infilled the canal remain intact and retain the form of the spicule, and might readily be mistaken for the entire spicule (Plate 45, figs. 14, 14*a*).

By treating the spicules of colloid silica with heated caustic potash the greater portion of their substance is dissolved, but their infilled canals remain, and not infrequently the form of the spicule is retained by a greenish-white mineral, which, when examined in Canada balsam, appears to be filled with exceedingly minute granules in a transparent ground-mass. These residuary spicules give a very slight double refraction between crossed nicols. In some instances one portion of a residuary spicule is of glauconite, or at least has the green appearance of this mineral, whilst the other portion is of this transparent mineral; and there is a gradual transition from one to the other. As nitric acid has no more influence on this mineral than it has on the glauconite, it is probably some silicate allied to glauconite.

These residuary spicules of glauconite and other silicates, which remain after dissolving away the silica by caustic potash are also produced under natural conditions, and they are very common in the loose material of the cavities in the chert of the upper greensand at Warminster in association with unaltered colloid spicules, and in similar positions at Ventnor, where they have been nearly wholly reduced to this condition (Plate 45, figs. 15–15*e* and 16).

Fossil siliceous spicules, with the silica in an amorphous condition, are of rare occurrence in comparison with the numerous instances in which the silica is cryptocrystalline or even crystalline, and they have not been previously noticed in this country. They are, however, abundant in the sponge-beds of the northern margin of the Weald, also at Wallingford, Warminster, and Penzlewood. Both spicules and entire sponges of amorphous silica are also common in glauconitic marls of senonian age in Westphalia and Hanover, from whence they have been described by Professor ZITTEL.*

The beds in which the spicules of amorphous silica are inclosed, also frequently contain an important quantity of silica in the colloid state, amounting in the case of the malm at Farnham, recorded by Messrs. WAY and PAINE,† to as much as 75 per cent. In some instances, however, whilst the spicules are of colloid silica, the inclosing matrix is of chalcedonic and even partially of crystalline silica, and calcite is also present.

The presence in the same beds of silica in an amorphous condition, with the siliceous spicules in a similar state, taken in connection with the fact that the beds are filled with empty spicular casts from which the spicules have been dissolved, and that many of the spicules are residuary forms which have lost all their soluble silica, points to the conclusion that the colloidal silica in the beds has been directly derived from the breaking up and dissolution of the sponge-remains.

The colloidal silica of the sponge-beds occurs in the form of minute granules, similar to those in the spicules, and also in a globular form, that is to say, in very minute bodies with circular outlines, though not strictly of a spherical form. The siliceous bodies can be examined in thin microscopic sections from the harder portions of the malm of Godstone and other places; but their characters are still better shown in the

* "Ueber Cœloptychium." 'Abhandlung der königl. Akad. der Wiss. zu München.' XII. Band, iii. Ab. Also, "Studien über fossile Spongien." *Id.*, XIII. Bd., i. Ab.

† 'Journal of the Royal Agricultural Society,' vol. xiv., p. 243.

fine powder from the cavities in the chert of Warminster, and in the powder which may be obtained with a needle from fractured surfaces of the friable portions of the malm of Merstham or Farnham. When this powder is mounted in water or in Canada balsam, it is seen under the microscope largely to consist of the globular bodies, either single and quite free (Plate 45, figs. 18, 19, 19*d*), or in groups of two, or three, or several individuals united together (Plate 45, figs. 18*a*, *b*, 19*a*, *b*, *c*). The single globules present well-defined circular outlines; the individuals forming the groups are also circular, except where in contact they partially coalesce, and their margins become abruptly truncated. In some instances the globules are ranged in a linear series, in which the individual components are only indicated by slight lateral indentations. Frequently these bodies are clustered round the residuary spicules and attached to the solidified canals of spicules, whose walls have been dissolved away (Plate 45, fig. 16). In the malm of Farnham the globules in some instances are aggregated into larger spherical bodies.

These globules, when magnified about 500 diameters, present well-marked variations. In the commonest forms there is a marginal ring, about one-sixth the diameter of the globule, which seems to be faintly striate, whilst the central portion has a granular appearance (Plate 45, fig. 18). In another form the surface is covered with faint striæ which radiate from an indefinite central granule (Plate 45, fig. 19*d*). In another form, which is nearly entirely confined to the fine material from the Warminster chert, there is a central well-marked circular area, from one-third to one-fifth the diameter of the globule (Plate 45, figs. 19, *a*, *b*, *c*). This central area is usually furnished with an ill-defined nuclear spot, and its margins are lighter than the outer portion of the globule, which is radiately striated. The striæ or rays are, in all cases, of a very faint character, and distinguishable only in the best preserved examples. The very smallest and simplest globules consist of perfectly clear silica without striæ or granules.

It is somewhat difficult to ascertain with precision the true form of these minute bodies. Some are certainly plano-convex discs, others are biconvex, and the smaller bodies may approach a spherical form.

The globules are very variable in size; the smallest forms are only ·0014 mm. in diameter, and from this there are all gradations of size to bodies of ·045 mm. in width, or more than thirty times the diameter of the smaller. The majority of them vary between ·013 and ·02 mm. in width.

By transmitted light the globules are translucent, and present the same pinkish tint as the colloidal silica of the spicules; by reflected light they have also the same bluish-white or opal aspect as the spicules. They are negative between crossed nicols, when freed from particles of calcite, which are often present, in the same deposits. They also readily dissolve when treated with caustic potash.

In the soft, friable beds of malm, the siliceous globules, which frequently constitute a large proportion of its mass, are mostly free, or but lightly consolidated together by pressure, but in the harder nodular portions they are inclosed by transparent chalcedonic silica, and seem to be gradually passing into the crypto-crystalline condition. They also appear at times to be invested with a surface layer of minute crystals of chalcedony.

In some cases the silica seems to have assumed the globular form within the sponge-spicules, but, as a general rule, the silica of the spicules must have been dissolved and then re-deposited as minute globules. I am not prepared to explain the causes which have produced this singular method of deposition; the chemical and physical forces which have brought it about have not been affected by extraordinary influences of heat or pressure, since the rocks are normal sedimentary deposits, and show no traces of alteration from these causes. There is no apparent reason why, under similar conditions of deposition and fossilisation, the sponge-remains of the siliceous and siliceo-calcareous deposits of the malm and firestone should have retained the original colloid condition of the silica, and the silica of the spicules when dissolved, should have assumed the globular form without passing from its hydrated condition, whilst in similar remains in most of the other greensand sponge-beds, the silica of the spicules has become altered to the more stable condition of chalcedony, and even to crystalline quartz, and, when the spicules have been dissolved, the silica has been deposited in layers and nodules of chalcedonic chert. The change of the originally colloid silica of the sponge-remains into the crypto-crystalline and crystalline condition is, indeed, that which nominally takes place in the course of fossilisation, and has been noticed in connexion with fossil sponges from silurian to upper cretaceous strata, and it is only under the particular circumstances, of which we are at present ignorant, that the colloidal state of the silica has been retained.

Sedimentary deposits consisting in part of colloidal silica in a globular form seem to be of rare occurrence; at all events, I cannot find any* previous notice of this character. But colloidal silica in a globular form has been recorded in rocks of volcanic origin. Thus VOGELSANG† describes and figures, from a quartz-trachyte from near Schemnitz, and also from Borsva, spherulitic bodies, the so-called *Globuliten*, of isotropic silica, and of approximately similar dimensions to the greensand globules. MICHEL LÉVY‡ has also discovered silica in a globular form and isotropic condition in eurites from Les Settons. It is worthy of notice, also, that there is a remarkable similarity, both of form and size, between the colloid siliceous globules of the greensand and the calcareous bodies artificially produced by the reaction of ammonia carbonate

* Professor ZITTEL mentions the fact that after treating with acid the now calcified, or partially calcified, siliceous sponges from jurassic strata the residue contains numerous rounded, rough, deeply indented siliceous discs. "Studien über fossile Spongien," I. Hexactinellidæ. 'Abhandl. der königl. bay. Akad. der Wiss.,' II. Cl., XIII. Bd., I. Ab., p. 14. I have not seen these bodies, but I should judge from the description of them that they are much larger, and that they further differ from those under consideration in being either crystalline or crypto-crystalline.

† 'Die Krystalliten,' pp. 139, 142, taf. xv., figs. 1, 2.

‡ 'Bulletin de la Société Géologique de France,' 3me ser., t. v., 1877, p. 140.

and calcium chloride, which have been figured by VOGELSANG.* Similar calcareous globules or discs of natural origin have been discovered by BARROIS† filling the cavities of shells and corals in the devonian limestones of Spain, which, though inorganic, he believes to be of the same nature as fossil and recent coccoliths.‡

There is at first sight a great similarity between the colloidal globules from the greensand and recent coccoliths from the Atlantic deep-sea mud, but the globules are round and not elliptical in figure, they do not occur in the sleeve-link form, and they coalesce together in a manner which has never been observed in coccoliths. There is therefore no ground for the supposition that they are silicified coccoliths. For the sake of comparison, I have represented on Plate 45, fig. 20, a coccolith of average size from the Atlantic ooze on the same scale as the globules.

The sponge-remains which are now of chalcedonic and crystalline silica have a very different aspect to those in which the silica is colloidal. By reflected light they have somewhat the appearance of ground glass, and when mounted in Canada balsam they become nearly invisible; in glycerine, however, their forms are very distinctly shown. The surface of the spicules in this condition is usually rough and eroded, so that it sometimes has a reticulated appearance; at other times it seems covered with minute circular spots of about ·006 mm. in diameter. These spots sometimes appear to be minute excavations in the surface of the spicule, in other cases they look like minute mammiform or botryoidal elevations. This surface character is very conspicuous in the spicules from Haldon and Blackdown, and has already been noticed by Mr. CARTER.§ The surface of spicules which have been changed to crystalline silica is less eroded than the exterior of those in which the silica is in the condition of chalcedony. These crystalline spicules frequently exhibit a finely radiate structure (Plate 45, fig. 17).

The canals of spicules in which the silica is either chalcedonic or crystalline are less regularly preserved than those of spicules of colloidal silica. In the majority of spicules no canal at all is visible, but this probably arises from the fact that the canal having been infilled with chalcedonic silica of the same character as that of the walls, cannot, either by ordinary or by polarised light, be distinguished therefrom. In other instances the canals are infilled with glauconite or with a light-brown or opaque mineral, not improbably iron peroxide. Not infrequently the solidified canal is discontinuous and broken up, and no longer occupies the normal position in the axis of the spicule, but is deflected to near its outer surface (Plate 42, figs. 3*b*, 6*a*). In many instances, even in these spicules of chalcedonic silica, the silica which has infilled the

* 'Die Krystalliten,' p. 87, taf. xi., fig. 1.

† 'Recherches sur les Terrains Anciens des Asturies et de la Galice,' p. 45, pl. xx., fig. 4.

‡ Dr. GÜMBEL also regards these minute, round, calcareous bodies, which he has discovered in limestones and marls of various geological epochs, as coccoliths, but their identity with the genuine coccoliths of the Atlantic, described by HUXLEY and by WALLICH, is open to doubt.

§ "Fossil Sponge-spicules of the Greensand compared with those of existing Species." Annals and Mag. Nat. Hist., s. 4, vol. vii., p. 114.

canal resists dissolution more than the spicular walls, and the solidified canal remains either wholly or partially free after the enclosing wall has been removed (Plate 45, fig. 13).

II. *Spicules replaced by glauconite and other silicates.*—Not only do these minerals infill the canals of the spicules, but they also replace the spicular walls as well. The replacement seems to have been gradually effected from within outwardly; the dissolution of the silica of the spicule taking place by the enlargement of the axial canal, and as this progresses the glauconite and allied minerals occupy the place of the silica until they constitute the entire spicule. These glauconitic spicules are very common in the malm and firestone of Merstham and Godstone, and also in the cavities of the chert at Ventnor. In this latter they are very strangely contracted and distorted, and assume figures which might have been produced by the gradual desiccation of a gelatinous body. The normally straight shafts and rays of the spicules are bent and curved in various directions, and even occasionally become spiral (Plate 45, figs. 15*a*, *b*, *c*, *d*).

III. *Spicules replaced by crystalline calcite.*—In every case in which this replacement occurs the matrix enclosing the spicules is of calcite, generally in a finely granular condition. The change seems to have taken place in the detached spicules in the same manner in which it has long been known to occur in entire fossil sponges. The original silica of the spicules has been dissolved subsequent to the enclosure of the spicules in the calcitic matrix, and the crystalline calcite has then filled up the moulds (Plate 40, fig. 4). In some cases the spicular canals have been infilled with glauconite before the calcitic replacement has been effected. The change to calcite is not complete in all the detached spicules in the same bed, since some occur in which the siliceous structure remains unaltered. Sponge-beds, with the spicules replaced by calcite, occur in the lower greensand at Maidstone, Tilburstow Hill, and Hythe, and in the upper greensand malm at Selborne.

IV. *Spicules represented by empty moulds.*—One of the commonest features of the sponge-beds is the empty moulds or casts of spicules with which the beds are filled, which have been produced by the complete dissolution of the siliceous spicules. In some cases the solidified canal has resisted the solvent influence which has removed the spicular wall, and now remains as a slender, smooth, delicate rod in the centre of the mould. These empty casts are present alike in the soft, friable, siliceous, and siliceo-calcareous sponge-beds of the malm and firestone, in the fine sedimentary deposits of the lower division of the upper greensand in the Isle of Wight, in the porous siliceous rock which generally accompanies chert, occasionally also in chert, and in a matrix entirely of calcite. It is to the dissolution and removal of the siliceous spicules that the sponge-beds owe their porous character and low specific gravity. The silica derived from the solution of the spicules appears usually to have been redeposited in the small interspaces between them, or to have accumulated to form nodular masses and layers of chert. Where the silica has been redeposited in the colloid condition the sponge-beds are usually friable and incoherent, but where it has been redeposited as chalcedony, the beds are of a hard, resistant character, and serve, as already mentioned, for whetstones and other economical purposes.

Beds of chert.—The chert associated with the sponge-beds of the lower and upper greensand varies from a light pellucid to a dark brown tint; it is readily translucent in thin sections. It is highly brittle, and sufficiently hard to scratch glass. It shows no reaction in nitric acid, and may thus be assumed to be free from calcite. Thin microscopic sections exhibit a nearly transparent ground-mass of chalcedonic—sometimes partially also of crystalline—silica, in which are numerous sponge-spicules, and also occasionally entire and fragmentary foraminifera and fragments of echinoderm structure. In some cases also grains of quartz-sand and glauconite are present. The chalcedonic silica forming the ground-mass can be seen in many cases to have been deposited in concentric layers over the enclosed siliceous and calcareous organic remains; it also, when partially crystalline, exhibits a radiate fibrous structure (Plate 40, fig. 3).

Throughout the chert, sponge-spicules are present, but owing to the fact that the spicules are usually of chalcedony, like the ground-mass of the chert in which they are enclosed, their outlines are very indistinct. But even when the spicules themselves cannot for this reason be recognised, their former presence is indicated by the solidified canals, which being of glauconite, or of silica of a different tint to that of the matrix, are distinctly shown (Plate 40, fig. 3.). In some cases the spicules have been dissolved after the chert has formed round them, leaving empty moulds.

Intimately allied to the chert is the yellowish-gray porous rock which frequently forms an exterior crust to the chert, but sometimes also forms independent beds. The rock is principally of chalcedonic silica, with which very frequently calcite is intermingled. The main difference between this rock and chert consists in its porous nature, arising from the fact that the spicules in it are but as empty casts, and the silica of these spicules has probably been deposited in the adjoining bands of chert.

There can scarcely be room for doubting that the beds and irregular masses of chert, which are found nearly everywhere in the strata of the lower and upper greensand in connexion with the detached spicules of sponges, have been derived from the silica of these sponge-remains; and from the same source has also originated the silica which, in many of the deposits, more particularly in the Blackdown Hills, has replaced the shells and tests of the mollusca and other calcareous organisms. The theory has, however, been advocated that the silica of chert has been derived rather as a direct deposit of this mineral from solution in sea-water, than as the product of the decomposition of the siliceous structure of sponges. Thus Dr. BOWERBANK * held that the sponges imbedded in the chert of the greensand possessed horny and not siliceous skeletons, and that the silica of the chert in which they were imbedded was attracted from the exterior medium by the animal matter, and not secreted therefrom by the

* Trans. Geol. Soc., ser. 2, vol. vi., p. 181.

living sponge. Professor T. RUPERT JONES * maintains the view that the silica of chert generally is derived directly from sea-water, and similar opinions as to the origin of the chert bands in the upper carboniferous limestones of Ireland have been put forward by Messrs. HULL and HARDMAN † and by M. RENARD ‡ with respect to the phthanites in rocks of the same age in Belgium.

It is a significant fact, however, in connexion with the chert-beds of the Irish upper carboniferous strata that some have been discovered filled with sponge-spicules like the chert of the English greensand, and this indicates a similar origin for the silica, and negatives the supposition of Professor HULL § that it was deposited "from warm shallow water charged with silica in solution, in which chemical reactions would be at once set up, favoured and promoted by tidal and other currents."

III.—THE NATURE OF THE SPONGES PRESENT IN THE SPONGE-BEDS.

As the skeletons of entire sponges, or even fragments of them, are nearly wholly absent in the sponge-beds, a determination of the character of the sponges of which they are formed must be based upon a study of the detached microscopic spicules which are indiscriminately mingled in the deposits. In the majority of cases these spicules are combined with the mechanically-derived materials of the beds, and with the silica produced from their own dissolution, into hard rock-masses, in which the form and proportion of the individual spicules are but very indistinctly and imperfectly shown on fractured or weathered surfaces or in thin microscopic sections. Under these conditions the knowledge to be obtained of the character of the spicules is very limited. In a few cases, however, the microscopic spicules occur loosely mingled together in incoherent beds of sand, or filling pockets or cavities in beds of chert, and it is then possible to obtain them perfectly free from the matrix, and to examine their characters under the microscope, in precisely the same manner as those of recent siliceous sponges. In one respect, indeed, these detached spicules sometimes present greater advantages for studying their individual forms than those of recent sponges, since, through gentle natural influences, they have become separated

* "Quartz and other Forms of Silica." 'Proceedings of the Geologists Association,' vol. iv., p. 447.

† "On the Nature and Origin of the Beds of Chert in the upper Carboniferous Limestone of Ireland." By Professor E. HULL, and "On the chemical Composition of Chert and the Chemistry of the Process by which it is formed." By E. T. HARDMAN. 'Scientific Transactions of the Royal Dublin Society,' vol. i., new series, 1878, p. 71.

‡ "Recherches lithologiques sur les Phthanites du Calcaire carbonifère de Belgique." 'Bulletin de l'Académie Royale de Belgique,' 2me s., t. xlvi., p. 471. The author expressly states that there is nothing to show that the infiltrated silica of these deposits has been derived from the decomposition of sponge-spicules or of diatoms. There are shown, however, in one of the figures (fig. 2) accompanying the paper, circular sections which more nearly resemble those of sponge-spicules than of crinoid-stems, to which they are assigned.

§ *Op. cit.*, p. 83.

from each other in a more perfect manner than it is always possible to obtain those of recent sponges by artificial means.

Spicules thus loosely imbedded have been met with in the lower greensand strata of Haslemere, Sevenoaks, and Tilburstow Hill, and from beds of upper greensand age in the vicinity of Warminster, Haldon, Blackdown, and Merstham. Figures are given in the accompanying plates of all the forms discovered; some of these are of general distribution, whilst others are restricted to the deposits of a single locality. With the exception of the spicules from Haldon and Blackdown, first partly described by Mr. PARFITT,* and subsequently and more completely by Mr. CARTER,† this is the first time that those from the lower greensand and from the other localities above mentioned in the upper greensand strata have been figured in detail.

Mention has already been made of the fact that the spicules of the sponge-beds referred to in this paper (the Faringdon sponge-gravel not being included) are exclusively those of sponges with siliceous skeletons. Representatives of each of the four orders of siliceous sponges occur, but in varying proportions. Monactinellid spicules of acerate, acuate, and cylindrical forms are very abundant, but, judging from their relative dimensions, the majority of these spicules belong to the tetractinellidæ, where they are associated with trifid spicules, rather than to those monactinellids whose skeletons are exclusively composed of uniaxial spicules. It is quite possible, however, that monactinellid sponges may have been also numerous in these sponge-beds, though we have but few spicules which can be definitely recognised as belonging to this order, for the spicules of most of the recent monactinellids are so minute and delicate that they would most likely be destroyed in fossilisation. Tetractinellid sponges are strongly represented, and the majority of the spicules in the sponge-beds are included in this order. There is a very great variety of the "zone" spicules of these sponges, each of which probably indicates a distinct species. The so-called "anchor" spicules, the globates and stello-globates, which form a dermal layer in some of these sponges, are also present. The lithistid sponges are principally represented by spicules belonging to the megamorina family. These are very numerous and very generally distributed. The skeletal spicules of the other families of lithistids are less common, and their generally minute dimensions may partly account for this fact. There is, however, a great number of the dermal spicules of lithistid sponges, which most probably belong to the tetracladina family. These dermal spicules are but seldom preserved on the surface of the entire lithistid sponges which have been discovered in the greensand, but they are present, quite detached from each other, in the sponge-beds, in a great variety of forms. The remains of hexactinellid sponges are comparatively rare, and they are limited to small fragments of the mesh and a few detached spicules probably belonging to the surface layer of the sponge.

* 'Transactions of the Devonshire Association for the Advancement of Science,' 1870.

† Ann. Mag. Nat. Hist., 1871, ser. 4, vol. vii., p. 113, pl. 7–10.

In recent tetractinellid sponges, the spicular elements of the skeleton are merely held in position by the sarcode, and the decomposition of this substance after the death of the animal would at once set the individual spicules free from each other. This structural character readily explains the complete manner in which these sponges have been broken up into their component spicules, for, though these are so abundant in the sponge-beds, I have not met with a single fragment of the skeleton with the spicules in their proper relative positions. Only under exceptionally favourable conditions of preservation could the entire body of the sponge be preserved in the fossil state. A few specimens have, however, been met with in the upper chalk of Yorkshire and Westphalia, but none, that I am aware of, in the greensand.

The skeletal spicules of the lithistid sponges are more intimately intertwined and interlocked together than is the case with tetractinellid sponges, and it is therefore a matter for surprise that in these sponge-beds no fragments of the sponges themselves should be found. The spicules are thoroughly detached from each other, and I have not met with a single instance of even two spicules naturally united together. Entire lithistid sponges are, however, occasionally very abundant, in the upper greensand more particularly; but they appear in only a few limited localities, and their preservation seems to be owing to the infilling of the skeleton by chalcedonic silica before it was exposed to those influences which in the sponge-beds destroyed the union of the spicules with each other.

It is a difficult matter to determine the extent to which the varied forms of these detached spicules may represent distinct species. There can be no doubt that numerous species are present in these sponge-beds; but many of the characters, which in recent sponges determine the species and genus, are based on the arrangement of the spicules in the skeleton, the combination of various forms of spicules in the dermal layer, the characters of the canal system, and many other features, which, of course, are entirely unrecognisable in these detached spicules. The only classification which can be attempted in the circumstances must rest on the features of the isolated spicules, and where the form and proportions of these are sufficiently distinct from those of known recent and fossil sponges, they may reasonably be regarded as belonging to new species. These spicules, it is true, furnish us with only one character of the species, that is, the form of the skeletal elements; but this, after all, is the most important feature. If the entire sponges should at any future time be discovered, of which, judging from present experience, there is but little probability, the provisional characters based on the spicules can then be supplemented by those derived from the entire skeleton.

It is not my purpose in the present paper to discuss in detail the characters and relation of the spicular contents of these greensand sponge-beds, beyond what may be necessary to indicate the groups to which they may belong, and to furnish grounds for comparison with those of similar deposits elsewhere. In those cases in which the spicules seem to me to indicate new species I have assigned a provisional name to them, following in this respect the example of Mr. CARTER and Prof. SOLLAS. Though these names may subsequently be displaced by the discovery of complete sponges, yet they are almost a necessity for purposes of reference.

The figures in the accompanying plates have all been drawn under the microscope by means of BECK's camera lucida, and their outlines may therefore be regarded as correct. It has not been practicable to figure all the forms on the same scale; the majority of them are enlarged either 40 or 60 diameters, a few are shown on the scale of 80, and in one instance the spicule has been enlarged 560 times. To avoid repetition, the titles of works in which similar detached spicules have been previously described, are given below under the names of the respective authors.*

Order Monactinellidæ ZITTEL.

1. *Reniera gracilis* (Plate 41, figs. 1–1*b*).—Cylindrical spicules, straight or slightly curved, smooth, evenly rounded at the ends. Average maximum length ·4 mm., width ·05 mm.

L. G. S.,† Haslemere, Surrey. U. G. S.,‡ Blackdown, Devonshire.

2. *Reniera obtusa* (Plate 41, figs. 2, 2*a*).—Smooth, slightly curved, cylindrical spicules, sometimes gradually tapering at one end. Length ·33 mm.; width ·058 mm.

U. G. S., Blackdown.

3. *Reniera cucumis* (Plate 41, figs. 3, 3*b*).—Slightly curved, smooth, either evenly cylindrical throughout, or slightly fusiform. Length ·466 mm., width ·066 mm.

U. G. S., near Warminster, Wilts; Haldon, Devonshire; Merstham, Surrey.

The cylindrical spicules above mentioned, though of similar form, are considerably

* CARTER, H. J.—"On Fossil Spicules of the Greensand compared with those of existing Species." Ann. Mag. Nat. Hist., ser. 4, vol. vii., pp. 112-141. 1871.

DUNIKOWSKI, E. V.—"Die Spongien, &c., der unterliassischen Schichten von Schafberg bei Salzburg." 'Denkschriften der kaiserlichen Akademie der Wissenschaften,' Wien. Bd. xlv., pp. 163-194. 1882.

HINDE, G. J.—I. 'Fossil Sponge-Spicules from the Upper Chalk.' 1880.

HINDE, G. J.—II. 'Catalogue of the Fossil Sponges in the British Museum.' 1883.

PARFITT, E.—"Fossil Sponge-Spicules in the Greensand of Haldon and Blackdown." 'Transactions of the Devonshire Association for the Advancement of Science.' 1870.

POČTA, P.—I. "Ueber isolirte Kieselspongiennadeln aus der böhm. Kreide-Formation." 'Sitzungsberichte der k. böhm. Gesellschaft der Wiss.' Prag, 1883.

POČTA, P.—II. "Ueber Spongiennadeln des Brüsauer Hornsteines." *Id.* 1884.

RUTOT, A.—"Note sur la Découverte de deux Spongiaires de l'Étage bruxellien." 'Annales de la Société Malacologique de Belgique,' tom. ix., 1874.

SOLLAS, W. J.—"On the Flint-nodules of the Trimmingham Chalk." Ann. Mag. Nat. Hist., ser. 5, vol. vi., p. 384. 1880.

WRIGHT, J.—"A List of the Cretaceous Microzoa of the North of Ireland." Belfast Nat. Field Club. 1875.

ZITTEL, K. A.—"Ueber Cœlophtychium." 'Abhandl. der könig. bay. Akad. der Wiss.,' II. Cl., XII. Bd. 1876.

† Lower greensand. ‡ Upper greensand.

larger than those of any recent species of *Reniera*. The form is very common in fossil sponge-beds, and cylindrical spicules of different dimensions have been described from the carboniferous (CARTER); Lias (DUNIKOWSKI); upper chalk of Norfolk (HINDE, SOLLAS); Westphalia (ZITTEL); Bohemia (POČTA).

4. *Reniera Zitteli*, POČTA, (Plate 41, figs. 4–4*e*; *op. cit.*, p. 6, taf. I., figs. 10–14). Acerate spicules, smooth, fusiform, acutely pointed. Length ·3 to ·45 mm., width ·02 to ·05 mm.

L. G. S., Haslemere. U. G. S., Blackdown.

5. *Reniera truncata* (Plate 41, figs. 5–5*f*).—Slender acerate fusiform spicules, very gradually tapering to the extremities, which are frequently truncate. Canals prominent, enlarging at the spicular ends. Length ·33 to 1 mm., by ·04 to ·058 mm. in width.

With these also may be associated small fusiform spicules in which the canals are open throughout their entire length. These forms are regarded by ZITTEL as immature spicules (Plate 41, figs. 5*g*, 5*h*).

U. G. S., Warminster, Merstham.

6. *Axinella gracilis* (Plate 41, figs. 7, 7*a*).—Smooth, slightly curved acuate spicules, with rounded but not inflated summits; tapering from one-third to one-half their length to an acutely pointed extremity. Length from ·55 to ·66 mm., width ·033 to ·05 mm.

L. G. S., Haslemere. U. G. S., Blackdown, Haldon, Warminster, Merstham.

7. *Axinella dispersa* (Plate 41, figs. 6–6*e*).—Smooth, straight, or curved acuate spicules; summits rounded but not inflated. Some examples taper gradually from the summit, whilst others are of an uniform width to the centre or even below, and then commence to taper. Ends acute or slightly truncate. Length from ·51 to 1 mm., by ·05 to ·075 mm. in width.

L. G. S., Haslemere. U. G. S., Warminster, Blackdown, Merstham.

8. *Axinella stylus* (Plate 41, figs. 8–8*d*).—Relatively large, smooth, straight or slightly curved acuate spicules. Summits truncate, rounded, and occasionally with a slight inflation. Rarely the spicules taper from the summit, but more generally they are of the same width to near the extremity, when they rapidly taper to an acute point. Length from 1·5 to 3·1 mm., width from ·085 to 1 mm.

L. G. S., Haslemere. U. G. S., Blackdown, Haldon, Ventnor.

9. *Spirastrella neocomiensis* (Plate 41, figs. 9, 9*a*).—Smooth, fusiform, straight or slightly curved spinulate spicules. Length 95 mm., width ·05 to ·075 mm.

L. G. S., Haslemere.

10. *Monilites Haldonensis*, CARTER (Plate 41, figs. 11–11*b*; *op. cit.*, p. 132, Plate 9, figs. 46, 47).—Cylindrical, slightly curved, moniliform spicules, with from five to eight rings. In some examples the inflations become depressed, giving an altogether different aspect to the spicule (fig. 11*b*). Length ·3 to ·53 mm., by ·09 mm. in thickness.

L. G. S., Haslemere. U. G. S., Haldon, Blackdown, Warminster.

11. *Esperites Haldonensis*, CARTER (Plate 41, fig. 12; *op. cit.*, p. 131, Pl. 9, fig. 43).—

Slender bihamate spicules with short obliquely incurved extremities. Length ·533 by ·041 mm. in width. It may be doubted whether these forms are really analogous to the bihamate spicules of the existing genus *Esperia,* since, as Mr. CARTER has already remarked, they are five times the size of the recent spicules.

U. G. S., Blackdown, Merstham.

12. *Dirrhopalum neocomiensis* (Plate 41, fig. 14).—Robust, smooth, straight, conical spicules, with an inflated, evenly-rounded summit, a slight constriction immediately beneath; from this, a gradual tapering to a sharply-pointed extremity. Length 1·22 mm., greatest width ·275 mm. The affinities of this form are very doubtful; it may have some relationship to the smooth conical spicules in the upper chalk, which I have named *Dirrhopalum planum,* and I therefore include it provisionally in the genus.

L. G. S., Haslemere.

13. *Hamate spicule* (Plate 41, fig. 18).—A smooth, cylindrical, hamate spicule, apparently perfect. Length ·366, by ·06 mm. in width. I do not know of any fossil or recent spicule at all similar to this.

L. G. S., Haslemere.

14. *Anomalous acerate spicule* (Plate 41, fig. 12).—Minute, smooth, acerate spicule, evenly cylindrical for the greater portion of its length, then tapering. One end is acute, the other obtuse. This exterior acerate form appears to inclose a spinulate form with a pear-shaped head and straight shaft, and within this is a central axial rod which seems to be the infilled canal. Length ·12 mm., width ·018 mm. The affinities of this peculiar spicule are doubtful. It is the smallest form which I have discovered in the sponge-beds, and only one example of it has been met with.

U. G. S., near Warminster.

Order Tetractinellidæ MARSHALL.

The distinguishing characters of the recent genera, *Geodia, Stelletta, Erylus,* and other allied forms, are based on the structural features of the dermal layer. In the greensand sponge-beds there are numerous examples of zone and anchor spicules, together with body acerates and the globates and globo-stellates of the dermal layer, but in their detached condition it is impossible now to determine the particular zone-spicules which may have been associated with the dermal spicules, and thus there can be no certainty in assigning the various forms of the zone-spicules to one or other of these genera, and it may therefore be desirable to adopt CARTER's general term *Geodites.* In recent sponges of this group, the species are characterised by a distinctive zone-spicule, and in like manner the different forms of these fossil zone-spicules may be regarded as indicating distinct species. The differences in the acerate spicules of distinct species are not recognisable in the fossil detached spicules, and they will have to be considered in a single group.

15. *Body-acerates of Geodites* (Plate 41, figs. 10–10*o*).—Straight, curved, or geniculate fusiform spicules, either acutely pointed or obtuse. The canals are only preserved as a rule in the spicules from Warminster and Merstham, in which the colloidal silica remains unaltered. The spicules vary from 1·1 to 3·12 mm. in length, and from ·04 to ·125 mm. in width. These spicules are very generally distributed in all the sponge-beds alike of the lower and upper greensand. The larger forms occur in the lower greensand of Haslemere, Sevenoaks, and Folkestone, and in the upper greensand of Blackdown and Haldon; whilst those from Warminster and the malm at Merstham are distinctly smaller forms.

16. *Pachymatisma virga* (Plate 41, figs. 15, 15*a*, 16).—Straight, slender, cylindrical spicules, terminating obtusely, occasionally also slightly inflated. Length 1·6 to 2 mm., by ·025 to ·041 mm. in width. With these there also occurs an inequally biclavate spicule (fig. 16), 1·16 mm. in length, by ·066 mm. in width. Dr. BOWERBANK has figured spicules of similar form, but much slenderer proportions, in *Pachymatisma Johnstonia* ('Brit. Sponges,' vol. i., Plate 1, figs. 12, 20; vol. iii., Plate 8, figs. 2, 3), and I place these provisionally in the same genus.

U. G. S., Blackdown, Haldon.

17. *Geodites Carteri* (Plate 41, figs. 17–17*k*).—Zone spicules, with straight or slightly curved shafts, gradually tapering from the head, terminating obtusely. The rays straight or slightly curved, simple or furcate, acutely pointed, projecting forwards. In some forms one of the rays is suppressed and the spicule resembles a two-pronged fork (17*b*, *k*). The rays are frequently inequal in length, and bifurcate irregularly. Total length 1·4 to 1·75 mm., by ·1 to ·15 mm. in width; the rays ·375 to ·45 mm. in length, by ·1 mm. wide. Abundant.

L. G. S., Haslemere, Tilburstow Hill, Sevenoaks (Folkestone division). U. G. S., Blackdown, Haldon.

18. *Geodites prœlongus* (Plate 42, figs. 1–1*c*).—Zone spicules, with elongated, nearly straight shafts, of nearly the same width throughout, or very gradually tapering. The head-rays are relatively short, simple, or bifurcate, usually slightly curved. They project obliquely forwards. Total length from 1·9 to 3·42 mm.; width, from ·113 to ·15 mm. The rays are from ·175 to ·425 mm. in length, by ·075 mm. in width.

L. G. S., Haslemere, Tilburstow Hill, Folkestone, Sevenoaks. U. G. S., Blackdown.

19. *Geodites robustus* (Plate 42, figs. 42, 2*a*).—Zone spicules robust, straight or slightly curved, tapering gradually, or of the same thickness for the greater part of their length. Rays also stout, simple, or bifurcate, projecting obliquely. Length 2·8 to 3·3 mm., width, ·17 to ·3 mm. The rays are from ·25 to ·45 mm. in length, by ·11 to ·15 mm. in thickness. Differs from the preceding form in being more robust throughout, and in the greater development of the rays.

L. G. S., Haslemere, Tilburstow Hill, Sevenoaks, Folkestone.

20. *Geodites audax* (Plate 42, figs. 3–3*c*).—Zone spicules robust, the shaft usually with a slight constriction just beneath the head, then gradually tapering to an acute

point, the head-rays all bifurcate, and in perfect specimens acutely pointed. Length 1·1 to 1·6 mm., width ·13 to ·2 mm.; rays ·33 mm. long, by ·116 mm. in thickness. Fig. 3*c* is probably the head of one of these spicules seen from beneath. Fig. 3*b* shows the peculiar manner in which the infilled canal has been distorted and broken up.

L. G. S., Haslemere.

21. *Geodites obtusus* (Plate 42, figs. 4, 4*a*).—Zone spicules robust, with straight shafts, usually slightly constricted near the head; below this they are tumid and then gradually taper. The rays are short, unusually thick, bifurcating near the summits, and forming short obtuse cones. Total length unknown; width ·35 mm.; rays ·35 mm. in length, by ·175 mm. in width.

L. G. S., Sevenoaks (Folkestone Division).

22. *Geodites politus* (Plate 42, figs. 5–5*c*).—Zone spicules, with straight, elongate, very gradually tapering shafts, and head-rays usually bifurcate, the terminations evenly rounded. The shafts incomplete in length, from ·17 to ·22 mm. in thickness. The rays ·25 by ·125 mm. Fig. 5*b* is probably the head of one of these spicules seen from below.

In the same beds an "anchor" spicule occurs (fig. 5*c*), with rounded head and three short, simple, recurved rays, which probably belongs to the same species as the zone spicules.

L. G. S., Folkestone, Tilburstow Hill. U. G. S., Merstham.

23. *Geodites pusillus* (Plate 42, figs. 6-6*b*).—Zone spicules, with straight or slightly curved shafts, usually constricted just below the rays; below this slightly tumid, and then gradually tapering. The rays are relatively short, simple, conical, and acutely pointed. Length 1·25 to 2 mm.; width ·125 to ·2 mm. Rays ·15 by ·075 mm.

L. G. S., Haslemere, Tilburstow Hill.

24. *Geodites Haldonensis*, CARTER (Plate 42, figs. 7–7*b*, 16, 16*a*; *op. cit.*, p. 129, Plate 10, figs. 58–67).—Zone spicules, with straight or curved, elongated, tapering shafts and straight or curved head-rays, either simple or bifurcate. Length 1·5 to 2·5 mm.; width ·075 to 11 mm. The rays ·175 by ·075 mm. Mr. CARTER has called attention to the different aspect of some of these spicules with curved shafts and simple rays, (figs. 7*b*, *e*), and suggests that they might belong to a different species. There are, however, intermediate forms between these and the spicules with bifurcate rays which indicate that they may all pertain to a single species. The "anchor" spicule (fig. 16) from the same beds was probably associated with these zone spicules. In comparing Mr. CARTER's figures with those which I have given, allowance must be made for the different scale on which they are drawn, Mr. CARTER's being on the scale of $\frac{75}{1}$, whilst mine are only $\frac{40}{1}$.

L. G. S., Sevenoaks. U. G. S., Haldon, Blackdown.

25. *Geodites divergens* (Plate 42, figs. 8, 8*a*, 11-11*b*).—Zone spicules, with short, stout shafts, straight or curved, gradually tapering, and terminating obtusely. The canals are prominent, and usually dilated at the extremity of the shaft. The rays are

strongly bifurcate, and the subdivisions usually diverge widely from each other. Total length from 1·07 to 1·77 mm.; width ·112 to ·16 mm. Rays ·17 to ·5 mm. in length by ·1 mm. in thickness.

L. G. S., Haslemere. U. G. S., near Warminster, Merstham.

26. *Geodites deflexus* (Plate 42, fig. 10).—Zone spicule, with straight, very gradually tapering shaft; the rays simple, extending for two-thirds of their length at approximately a right angle to the shaft, and then abruptly recurved. Total length unknown, the shaft is ·1 mm. in width. Rays ·375 mm. long by ·087 mm. wide.

U. G. S., Blackdown.

27. *Geodites Wrightii* (Plate 42, fig. 9; Plate 41, fig. 13).—Zone spicules with straight tapering shaft and stout rays, projecting obliquely forwards. The rays are incipiently bifurcate at their extremities. The rays and the greater portion of the shaft are moniliform. Length 1·375 by ·2 mm. in width. Rays ·3 by ·125 mm. Fragmentary specimens indicate much larger forms than the example figured. In the upper chalk examples of this form the rays are uniformly simple and more slender than in the greensand specimens.

Acuate moniliform spicules (Plate 41, fig. 13), rarely occur in the same beds with the trifid forms, and, though much larger in size, they may have belonged to the same species with the trifid spicules.

L. G. S., Haslemere, Godalming. U. G. S., Warminster.

28. *Geodites planus* (Plate 42, figs. 13–13*c*).—Zone spicules with slender, elongate, gradually tapering shafts, and simple or bifurcate head-rays, which extend nearly at right angles to the shaft. In some examples only two of the three head-rays are developed. Length ·875 to 1·72 mm.; width ·062 to ·125 mm. Rays ·175 to ·3 mm., by ·05 to ·09 mm. Very abundant.

L. G. S., Haslemere. U. G. S., Blackdown, Haldon, Warminster, Merstham.

29. *Geodites gracilis* (Plate 42, figs. 12–12*e*).—Slender spicules, with straight tapering shafts, and short simple or bifurcate head-rays, which extend obliquely forwards. Length 1 to 1·7 mm. by ·07 to ·1 mm. Rays ·225 by ·075 mm.

U. G. S., Blackdown, Haldon, Warminster, Penzlewood, Merstham.

30. *Globate and globostellate spicules of the dermal layer of Geodites* (Plate 43, figs. 2–2*f*).—The spicules forming the dermal crust of this group of sponges are abundantly present. There are two varieties of globates; one is nearly spherical in form (fig. 2*c*), the surface smooth and apparently destitute of hilum. The average diameter is ·233 mm. This form only occurs in the lower greensand at Haslemere. The other variety is elliptical or reniform (figs. 2*a*, 2*b*,), surface smooth, with a well-marked depression or hilum. The average size is ·137 by ·09 mm. It occurs in lower greensand at Haslemere, Sevenoaks, Tilburstow Hill, and in upper greensand at Warminster, Blackdown, Merstham.

One variety of globostellate is nearly spherical, ·137 mm. in diameter, its surface is thickly covered with minute blunted elevations (fig. 2*d*). It occurs in the upper greensand at Warminster and Merstham, and it has been figured from the upper chalk of Westphalia (ZITTEL).

Another globostellate (figs. 2*e*, *f*) has a spherical body with stout, conical spines projecting from its surface. Entire diameter ·2 mm.; length of spines ·075 mm. Lower greensand, Haslemere.

31. *Stellettites?* sp. (Plate 42, figs. 14–14*e*).—Zone spicules, in which the shafts are greatly reduced, whilst the head-rays are, as a rule, widely extended in a nearly horizontal direction and symmetrically bifurcate. The great variety of size of these spicules indicates that they may belong to more than a single species. It is possible that some may belong to the dermal layer of lithistid sponges. It is a very common form, and occurs also in the lower lias of Schafburg (DUNIKOWSKI), in the upper chalk of Norfolk and Westphalia (ZITTEL), and in the eocene of Brussels (RUTOT).

L. G. S., Folkestone. U. G. S., Blackdown, near Warminster, Penzlewood, Merstham.

32. *Stellettites callodiscus*, CARTER sp. (Plate 43, fig. 3; *op. cit.*, p. 123; Plate 9, fig. 40).—Delicate flattened discs, circular or slightly elliptical in outline, with a well-defined smooth margin. Radially disposed at equal intervals near the margins are from twelve to fourteen flask-shaped apertures; between each of these there are two and occasionally three smaller sub-oval apertures. A series of canals radiating from the common centre of the disc extends to near its periphery. One of these canals is present between each of the larger flask-shaped apertures. A fairly large spicule is ·313 by ·263 mm. In spicules which are in process of breaking up, the smooth margin disappears, the flask-shaped apertures open on the outer border, and the canals are greatly widened, so that the spicule has an altogether different appearance.

U. G. S., Blackdown, Warminster. This form is also present in the upper chalk of Norfolk (HINDE) and Westphalia (ZITTEL).

33. *Tethyopsis Haldonensis*, CARTER, pars. (Plate 44, figs. 15, 15*a*; Plate 43, figs 1–1*d*; *op. cit.*, Plate 10, fig. 70, non fig. 69).—Trifid spicules, with straight, elongate shafts and rays, usually inequal in length, and simple, which extend at a wide angle, and generally exhibit a slight recurvature. Frequently only two rays are developed. Length of shaft (incomplete) 1·9 mm.; thickness ·075 to ·13 mm. Rays ·3 to ·62 mm. in length, by ·075 to ·125 mm. in thickness.

L. G. S., Haslemere, Folkestone. U. G. S., Blackdown, Haldon.

34. *Small trifid spicules of different species* (Plate 42, figs. 17–17*k*).—The affinities of these small spicules are doubtful; figs. 17, 17*a*, *b* may be either young spicules of *Geodites*, or the dermal spicules of a lithistid sponge; the clavate spicules, 17*c*, *d*, *e*, approximate to the four-rayed spicules of *Pachastrella;* the obtuse spicules, 17*g*, *h*, *i*, are now in the condition of glauconite, and, though apparently perfect, may vary considerably from their original forms in silica; and the small spicule with much branched rays (17*k*) is very probably the dermal spicule of a lithistid sponge.

U. G. S., Blackdown, near Warminster, Merstham, Ventnor.

35. *Pachastrella* (*Dercitus*) *Haldonensis*, CARTER (Plate 43, figs. 4–4*i*; *op. cit.*, p. 130;

Plate 10, fig. 71).—Four-rayed spicules; the rays straight, simple, sub-equal, tapering from the central junction to an acute point, rarely rounded at the ends (fig. 4*d*). Very variable in size; the rays are from ·35 to ·825 mm. in length, and from ·075 to ·125 mm. in width.

With the above are sometimes associated smaller spicules (figs. 5, 5*a*, *b*) with relatively shorter and plumper rays, which may probably belong to a distinct species. They are similar to those from the upper chalk which I have named *P. Carteri* (*op. cit.*, i., p. 46; Plate 3, figs. 29, 31). The rays are ·225 to ·35 mm. in length, by ·08 mm. in width.

These spicules are very generally distributed throughout the sponge-beds of the lower and upper greensand. Similar forms are present in the carboniferous (HINDE), lias (DUNIKOWSKI), chalk of England (SOLLAS, HINDE), Ireland (WRIGHT), Westphalia (ZITTEL), and in the eocene of Brussels (RUTOT).

36. *Pachastrella* (*Monilites*) *quadriradiata*, CARTER (Plate 43, figs. 6, 6*a*,; *op. cit.*, p. 132, Plate 9, figs. 44, 45).—Spicules of the same general form as the preceding, but, as a rule, much smaller, and the rays are throughout moniliform. Length of rays ·25 mm., thickness ·05 mm.

L. G. S., Haslemere. U. G. S., Blackdown, Haldon, Warminster.

Order: Lithistidæ, O. SCHMIDT.

Family: Megamorina, ZITTEL.

37. *Doryderma*, sp. (Plate 43, figs. 7–7*z*).—Detached spicules of sponges of the Megamorina family, of which the genus *Doryderma* may be taken as the type, are extremely abundant. They are of the most irregular and varied forms, generally elongate branching spicules with arms of unequal length, which terminate either in an obtuse point or in a slightly concave expansion. The branches in some of the larger spicules (figs. 7*q*, *r*, *s*, *u*) all terminate obtusely, and these appear to belong to the stem of the sponge, whilst the spicules whose rays terminate in an expansion belong to the body portion of the sponge. The larger spicules measure 2·5 mm. by ·175 mm., whilst a small form is only ·4 mm. by ·062 mm. These spicules probably belong to several different species.

L. G. S., Haslemere, Godalming, Tilburstow Hill, Sevenoaks. U. G. S., Blackdown, Haldon, Warminster, Penzlewood, Merstham, Ventnor.

38. *Carterella*, sp. (Plate 45, figs, 1–1*c*).—Elongate, curved spicules with blunted extremities and irregularly notched surfaces. Length ·95 to 1·4 mm., width 0·75 mm.

U. G. S., Warminster.

Family Anomocladina, ZITTEL.

39. *Mastosia neocomiensis*, HINDE (Plate 45, figs. 2–2*k*; *op. cit.*, ii., p. 57; Plate 10, fig. 4).—Spicules with spherical or sub-spherical centres, from which short arms or rays, from three to five in number, extend in various directions. Rays usually simple, though occasionally bifurcate near their ends. They terminate in slightly concave expansions. The nodes are about ·22 mm. in thickness, and the rays from ·12 to ·27 mm. in length, by ·62 mm. in thickness.

L. G. S , Haslemere, Tilburstow Hill, Petworth. U. G. S., Haldon, Warminster.

Family Rhizomorina, ZITTEL.

40. *Chenendopora*, sp. (Plate 45, figs. 3, 4–4*d*).—Branching spicules of irregular form, their surfaces covered with blunted spines or tubercles. Length ·53 mm. by ·085 to ·15 mm. in width.

L. G. S., Haslemere, Tilburstow Hill. U. G. S., Blackdown, Warminster, Penzlewood.

Family Tetracladina, ZITTEL.

41. *Ragadinia*, sp. (Plate 45, figs. 5, 5*a*, *b*).—Small, four-rayed spicules of the skeleton; one of the rays is reduced to a prominent tubercle, whilst the others are irregularly annulated.

L. G. S., Haslemere, Tilburstow Hill. U. G. S., Warminster.

42. *Siphonia*, sp. (Plate 45, figs. 6, 6*a*–6*f*).—Four-rayed spicules of the skeleton; the rays usually smooth, sub-equal, and branching at their extremities.

L. G. S., Tilburstow Hill, Sevenoaks. U. G. S., Blackdown, Haldon, Warminster, Penzlewood, Merstham.

Spicules of the dermal layer of Tetracladine Lithistids (Plate 44, figs. 1–15).

These spicules occur in an almost unlimited variety of form, but as suggested by OSCAR SCHMIDT,* they all appear to originate from modifications of the summit-rays of the trifid spicule. The simplest form of dermal spicule in these sponge-beds consists of three horizontally extended simple rays with irregular lateral lobate extensions, and a minute ray or shaft at right angles to the others (figs. 4, 4*a*). This simple type is, however, of rare occurrence; the large majority of the dermal spicules are derived from forms in which the three primary rays are symmetrically bifurcate, and each of the subdivisions is variously lobed and branched in a horizontal plane. Thus in one of the less modified examples (figs. 1, 1*a*) the rays of the typical spicule are merely expanded laterally and sinuated; in another the lateral expansion is increased, and

* 'Die Spongien des Meerbusen von Mexico,' 1stes Heft, 1879, p. 22.

the margins are smooth (fig. 2), whilst in others the margins are sinuous and notched). (figs. 3, 3*a*, *b*). In the more complex forms the rays are divided and branched in an extraordinary variety of ways; in some cases the subdivisions are narrow (figs. 7, 7*a*), whilst in others they are mere lobate extensions (figs. 12, 12*b*). The greatest modification occurs in the spicules, which are simple horizontal discs with lobate (fig. 13*b*), jagged (13*c*), or smooth margins (14, 14*a*). In these all traces of the typical trifid spicule have disappeared in the external form, but the minute three-branched canal present in some of these discoid spicules (fig. 14) indicates very clearly that they have originated from the same fundamental type as the branched dermal spicules. As a general rule the canals in these dermal spicules extend only a short distance from their centres (figs. 10*a*, 11), and do not reach the extremities of the subdivided rays. In but slightly modified examples, however, the canals normally extend to the extremities of the rays (figs. 2, 3, 3*a*).

These dermal spicules vary in diameter from ·316 to ·816 mm., and the rays are from ·024 to ·1 mm. in width. They are as a rule much larger than the average dermal spicules of recent lithistids, as may be seen from those of *Discodermia sinuosa*, Carter (figs. 15, 15*a*), which have been figured on the same scale as the fossil forms for comparison.

These dermal spicules belong in all probability to many distinct species of lithistid sponges, but they are so rarely found in their natural position on the surface of these sponges in the fossil state, that very little is known at present of the particular forms belonging to each species. The only lithistid sponge from the English greensand in which the dermal spicules have been found in position, is *Hallirhoa agariciformis*, Benett, sp.,* and they are of the lobate character shown in figs. 12, 12*b*, 12*d*. As numerous examples of the tetracladina genera *Siphonia*, *Hallirhoa*, *Ragadinia*, *Kalpinella*, and *Rhopalospongia* are known from the greensand, which, there can be no doubt, possessed a definite spicular dermal layer, we may conclude that these dermal spicules belong to these genera.

The dermal spicules are very generally distributed throughout the greensand, but they are more particularly abundant in the lower greensand at Haslemere, and in the upper greensand at Blackdown, Haldon, and Warminster.

Order Haxactinellidæ, O. Schmidt.

In contrast with the abundance of the detached spicules of tetractinellid and lithistid sponges in the sponge-beds, those of the above order are few and of rare occurrence. There are fragments of the skeletal mesh of two species, in which the nodes are compact; in one (Plate 45, figs. 7, 7*a*, *b*) the rays are robust and the distance from node to node is ·3 mm.; in the other (fig. 8) the mesh is smaller and the nodes are

* See Catalogue Fossil Sponges in the British Museum, pl. 15, fig. 1*b*.

only ·17 mm. apart. Both these forms are present in the lower greensand at Haslemere, and the smaller also occurs at Sevenoaks and Tilburstow Hill.

Portions of the mesh of another species in which the nodes are octahedral occur in the malm at Merstham (fig. 9).

43. *Stauractinella*, sp. (Plate 45, figs. 10, 10*a*-*c*).—Free hexactinellid spicules with straight or curved rays; the rays are nearly of an even thickness throughout and truncated at their ends. The nodes are compact, in some only five rays are developed. The rays are from ·2 to ·53 mm. in length, and ·04 mm. in thickness.

L. G. S., Haslemere, U. G. S., Blackdown, Merstham.

44. *Gomphites Parfitti*, CARTER (Plate 45, figs. 11, 11*a*; *op. cit.*, p. 127. Plate 9, figs. 38, 39).—Free spicules, in which only five rays are developed, the rays short, tapering, and either straight or curved. The rays are ·15 to ·416 mm. in length, by ·066 mm. in thickness.

U. G. S., Blackdown, Haldon.

Whilst some of the above-mentioned spicules are widely distributed, and range from the lower greensand to the upper chalk, and even to the eocene, there are others which, so far as our present knowledge extends, are restricted to a single geological horizon. Thus, for example, the distinctive zone spicules of *Geodites*, which I have named *Geodites robustus*, *G. pusillus*, *G. audax*, and *G. obtusus*, have as yet only been found in the lower greensand; *Geodites deflexus*, *G. Haldonensis* and *Tethyopsis Haldonensis*, are apparently restricted to the lower or Blackdown division of the upper greensand; *Geodites Carteri* and *G. prælongus* occur in both divisions; and *G. Wrightii* ranges from the lower greensand to the upper chalk.

The character of the sponges in these lower and upper greensand sponge-beds bears a very general resemblance to those which have been deposited, under similar detached conditions, in the upper chalk of Norfolk, the North of Ireland, Westphalia, and Bohemia. In all these localities the large majority of the detached spicules belong to tetractinellid sponges of the same genera as those in the greensand, and with these are mingled, in varying proportion, those of the other orders of siliceous sponges. As a rule entire sponges do not occur in connexion with these detached spicules, but in Westphalia hexactinellid sponges are present in the same beds.

Recent deposits consisting largely of the detached spicules of disintegrated siliceous sponges, similar to those of the greensand, do not appear to have been met with in the dredging expeditions of these last few years, or at all events there is no record of them, but on the other hand *entire* siliceous sponges are stated by the late Sir WYVILLE THOMPSON* to be very abundant in some areas of the Atlantic.

* "Depths of the Sea," pp. 416, 430.

SUMMARY.

I have pointed out in this paper the occurrence in the lower and upper greensand strata of the Wealden area, the Isle of Wight, and the South-Western counties, of beds of rock, formed to a large extent of the detached spicular remains of siliceous sponges, and thus distinctly of organic origin. Their true characters have not been generally recognised, and they have usually been described as deposits of sandstone, chert, malm, hearthstone, firestone, &c. In the lower greensand these beds are mainly developed in the lower or Hythe division, and they are exposed at Haslemere, Midhurst, Petworth, Godalming, Tilburstow Hill, near Godstone, Sevenoaks, Maidstone, and at Hythe. The sponge-beds vary from three-quarters of an inch to three feet in thickness; between them, as a rule, there are intervening beds of sand or sandstone. The greatest total thickness of the sponge-beds exposed in one section is 11 feet. Sponge-beds are less common in the higher or Folkestone division of the lower greensand, but they are numerous at Folkestone itself, and reach a total thickness of more than eight feet, and there is also a thin bed in this division at Sevenoaks. The lower greensand strata at Faringdon, in Berkshire, is of an altogether different character to those of the same formation, in the area treated of in this paper, and the sponges which abound therein are likewise entirely different, being calcisponges and retaining their entire forms.

The sponge-beds in the upper greensand are of two distinct types, one of which is shown on the northern and western margin of the Weald, and the other in the Isle of Wight, and further westwards in the counties of Wilts, Somerset, Dorset, and Devon. In the first-named district the sponge-beds are of a soft, grayish-white, siliceous or siliceo-calcareous rock, known under the names of malm, hearth, or firestone. In this the sponge-spicules principally occur in the negative form of minute empty casts, the presence of which renders the rock extremely light and porous. The beds can be traced nearly continuously along the northern and western margin of the Wealden area, and they are well shown at Godstone, Merstham, near Reigate, Betchworth, Farnham, and Selborne. Further northwards they are present at Wallingford, in Berkshire. The beds vary in thickness from 15 feet at Merstham to 60 feet at Farnham.

In the more typical upper greensand of the Isle of Wight and the south-western counties, the sponge-beds consist of thick layers of chert and porous siliceous rock at the summit of the series, immediately beneath the so-called chlorite marl; whilst in the lower division the sponge remains principally occur in loose quartzitic sands with siliceous accretions. The chert or sponge-beds at the top of the upper greensand are best exposed at Shanklin, Ventnor, and the Undercliff, in the Isle of Wight, at Warminster in Wiltshire, and Penzlewood in Somersetshire. They vary from 10 to 25 feet in thickness. The sponge-beds of the lower division are scarcely recognisable in the Isle of Wight, but they attain a thickness of 10 to 20 feet on the summit of the Blackdown and Haldon Hills in Devonshire, and at Axmouth in Dorsetshire. The chert here is only present in beds of subordinate importance.

Sponge-beds of similar characters to those of the greensand have been described from the Hils-sandstein, in Westphalia, which is of neocomian age, and, judging from specimens which I have examined, the "gaize de l'Argonne," which is largely developed in the Ardennes, and the "meule de Bracquegnies," in Belgium, are sponge-beds, filled with spicules and spicular casts like those of the greensand.

The sponge-remains in the various beds are exclusively those of siliceous sponges. In some the silica of the spicules yet retains its original colloidal condition, in which it is negative to polarised light, and readily soluble in caustic potash. The matrix of the sponge-beds of the malm and firestone is also to a large extent of colloidal or amorphous silica, and this material has been deposited in the form of minute globules or discs, and it seems to have been derived from the sponge-spicules, with the empty casts of which the beds are throughout filled.

More generally the original amorphous silica of the sponge-remains has been altered to chalcedony, and the chert and porous siliceous rock accompanying it, which is filled with traces of the spicules, are likewise of chalcedony; occasionally the chalcedony gives place to crystalline silica.

Glauconite very commonly fills the canals of the spicules, and remains after the spicular walls have been removed; it also replaces the spicular walls.

In some sponge-beds the spicules have been nearly entirely replaced by crystalline calcite; they are imbedded in a matrix of granular limestone.

As a general rule the sponge-spicules are inclosed in a compact matrix, in which their forms can only be partially studied, but under certain conditions they are loosely distributed in sand or in fine powder in cavities in chert, from whence they can be obtained quite free from matrix. The sponge-beds appear to be wholly composed of detached, free spicules; entire sponges are absent. These spicules belong to numerous species. All four orders of siliceous sponges are represented, but those of monactinellid and hexactinellid sponges form but a small proportion, whilst those of tetractinellid and lithistid sponges, more particularly of the megamorina family, are extremely abundant.

Explanation of Plates.

PLATE 40.

Fig. 1. Microscopic section of a sponge-bed in the upper greensand at Warminster, showing entire and fragmentary spicules of colloid silica, inclosed in a matrix of transparent chalcedonic silica. Colloid silica in the globular form is also present. × 40 diameters.

Fig. 2. Microscopic section of a nodule from the upper greensand firestone at Godstone, filled with spicules of colloid silica in a siliceo-calcareous matrix. ×40 diameters.

Fig. 3. Microscopic section of chert from the upper greensand at Penzlewood, showing spicules and spicular canals of chalcedonic and crystalline silica, in a matrix of the same material. ×40 diameters.

Fig. 4. Microscopic section of a sponge-bed in the lower greensand at Tilburstow Hill, showing spicules replaced by crystalline calcite, inclosed in a matrix of granular calcite. ×40 diameters.

Fig. 5. Microscopic section of the malm rock from Merstham, showing a portion of a sponge-spicule in which the silica is in the globular form. The matrix largely consists also of colloid globular silica, with mica scales, grains of glauconite, and a small proportion of chalcedonic silica. ×150 diameters.

Fig. 6. Microscopic section of a sponge-bed in the upper greensand at Warminster, showing a portion of a sponge-spicule, the central part of which consists of colloid silica in a globular form, whilst the exterior is of chalcedonic silica. ×150 diameters.

Fig. 7. A fractured surface of the upper greensand "malm" at Merstham, showing the empty casts of spicules in a matrix of globular silica. ×40 diameters.

Fig. 8. A portion of a sponge-spicule from Warminster, in which the colloid silica is traversed by curved lines. ×150 diameters.

Fig. 9. A microscopic section of a portion of another spicule, still further magnified, in which the lines appear as incomplete elliptical rings with smooth rims. ×560 diameters.

PLATE 41.

Figs. 1, 1*a*, *b*. *Reniera gracilis.*—Haslemere, Blackdown. ×60 diameters.

Figs. 2, 2*a*. *Reniera obtusa.*—Blackdown. ×60 diameters.

Figs. 3, 3*a*, *b*. *Reniera cucumis.*—Near Warminster. ×60 diameters.

Figs. 4, 4*a*–*e*. *Reniera Zitteli*, Počta.—Haslemere, Blackdown. ×60 diameters.

Figs. 5, 5*a*–*f*. *Reniera truncata.*—Near Warminster. ×60 diameters.

Figs. 5*g*–*h*. *Reniera truncata?* Immature spicules in which the canal remains open throughout its length.—Near Warminster. ×60 diameters.

Figs. 6, 6*a*–*e*. *Axinella dispersa.*—Blackdown; near Warminster, Merstham. ×60 diameters.

Figs. 7, 7*a*. *Axinella gracilis.*—Haslemere, Blackdown. ×60 diameters.

Figs. 8, 8*a*–*d*. *Axinella stylus.*—Haslemere, Blackdown. ×40 diameters.

Figs. 9, 9*a*. *Spirastrella neocomiensis.*—Haslemere. ×60 diameters.

Figs. 10, 10*a*–*o*. *Geodites.* Acuate spicules of different forms and dimensions belonging to various species.—Haslemere, Blackdown, Haldon; near Warminster, Merstham. ×40 diameters.

Figs. 11, 11*a–b*. *Monilites Haldonensis*, CARTER.—Blackdown; near Warminster ×80 diameters.

Fig. 12. *Esperites Haldonensis*, CARTER.—Blackdown. ×60 diameters.

Fig. 13. *Geodites Wrightii*. Acuate spicule, fragmentary. ×40 diameters.

Fig. 14. *Dirrhopalum neocomiensis*.—Haslemere. ×40 diameters.

Figs. 15, 15*a*, 16. *Pachymatisma? virga*.—Blackdown, Haldon. 15*a*, ×40 diameters, figs. 15, 16, ×60 diameters.

Figs. 17, 17*a–k*. *Geodites Carteri*. Zone spicules, showing various modifications of the head rays. In figs. 17*b*, *k*, only two of the rays are developed.—Haslemere, Blackdown. ×40 diameters.

Fig. 18. *Hamate spicule*.—Haslemere. ×60 diameters.

PLATE 42.

Figs. 1, 1*a–c*. *Geodites prælongus*. Zone spicules with simple and bifurcate head-rays. —Haslemere, Sevenoaks. ×40 diameters.

Figs. 2, 2*a*. *Geodites robustus*. Zone spicules.—Haslemere. ×40 diameters.

Figs. 3, 3*a–c*. *Geodites audax*. Zone spicules. Fig. 3*b* shows the peculiar manner in which the infilled axial-canal has been contorted and displaced. Fig. 3 is the head of a spicule seen from beneath.—Haslemere. ×40 diameters.

Figs. 4, 4*a*. *Geodites obtusus*. Zone spicules, the shafts incomplete.—Sevenoaks. ×40 diameters.

Figs. 5, 5*a–c*. *Geodites politus*. Zone spicules and anchor spicule (5*c*.)—Merstham, Folkestone. ×40 diameters.

Figs. 6, 6*a*, *b*. *Geodites pusillus*. Zone spicules.—Haslemere. ×40 diameters.

Figs. 7, 7*a–g*. *Geodites Haldonensis*, CARTER. Zone spicules with variously modified head-rays.—Blackdown. ×40 diameters.

Figs. 8, 8*a*. *Geodites divergens*. Zone spicules with very prominent canals.—Near Warminster. ×40 diameters.

Fig. 9. *Geodites Wrightii*. Zone spicule, moniliform.—Haslemere. ×40 diameters.

Fig. 10. *Geodites deflexus*. Zone spicule, shaft incomplete.—Blackdown. ×40 diameters.

Figs. 11, 11*a*, *b*. *Geodites divergens*. Zone spicules.—Near Warminster. ×40 diameters.

Figs. 12, 12*a–e*. *Geodites gracilis*. Slender zone spicules.—Blackdown; near Warminster, Merstham.

Figs. 13, 13*a–c*. *Geodites planus*. Zone spicules with horizontally extended head-rays. Haldon; near Warminster. ×40 diameters.

Figs. 14, 14*a–e*. *Stellettites?* sp. Zone spicules, with reduced shaft and horizontally extended head-rays.—Blackdown; near Warminster, Merstham. ×60 diameters.

Figs. 15, 15*a*. *Tethyopsis Haldonensis*, CARTER. Zone spicules.—Blackdown, Haldon. ×40 diameters.

Figs. 16, 16*a*. *Geodites Haldonenis*, CARTER. "Anchor" spicules, shafts incomplete. —Haldon, Penzlewood. ×40 diameters.

Figs. 17, 17*a–k*. Small trifid spicules of different species. Figs. 17, 17*a*, *b*, young spicules of *Geodites*. ×60 diameters. Figs. 17*c*, *d*, *e*, allied to *Pachastrella*. Figs. 17*g*, *h*, *i*, spicules replaced by glauconite. Fig. 17*k*, dermal spicule of lithistid. ×60 diameters.—Blackdown, Warminster, Merstham, Ventnor.

PLATE 43.

Figs. 1, 1*a–d*. *Tethyopsis Haldonensis*, CARTER.—Blackdown. ×40 diameters.

Figs. 2, 2*a–f*. *Geodites*. Globate and globostellate spicules of the dermal layer of various species.—Haslemere, Blackdown, near Warminster. ×80 diameters.

Fig. 3. *Stellettites callodiscus*, CARTER. Spicule of the dermal layer.—Near Warminster. ×80 diameters.

Figs. 4, 4*a–i*. *Pachastrella Haldonensis*, CARTER. Four-rayed spicules of the skeleton. Blackdown; near Warminster, Merstham. Fig. 4*a*. ×60 diameters; the others ×40 diameters.

Figs. 5, 5*a*, *b*. *Pachastrella Carteri*.—Haslemere, Blackdown, Merstham. ×40 diameters.

Figs. 6, 6*a*. *Pachastrella quadriradiata*, CARTER.—Blackdown, near Warminster. ×80 diameters.

Figs. 7, 7*a–z*. *Doryderma*. Spicules of various forms belonging to the body and stem of different species of this and allied genera of the megamorina family of lithistidæ.—Haslemere, Blackdown, Haldon, near Warminster, Merstham. ×40 diameters.

PLATE 44.

Figs. 1–14. Various forms of spicules of the dermal layer, probably belonging to different species of tetracladine lithistidæ, of the genera *Siphonia*, *Hallirhoa*, *Ragadinia*, &c.—From Haslemere, Blackdown, Haldon, near Warminster, Merstham. All drawn by means of the camera lucida to the same scale of 60 diameters.

Figs. 15, 15*a*. *Discodermia sinuosa*, CARTER. Spicules of the dermal layer of this existing species, for comparison with those of the fossil lithistids. From the Gulf of Manaar. Drawn from examples of the typical species, kindly presented to the Author by Mr. H. J. CARTER, F.R.S. × 60 diameters.

PLATE 45.

Figs. 1–1*c*. *Carterella*, sp. Skeletal spicules.—From near Warminster. × 40 diameters.

Figs. 2–2*k*. *Mastosia neocomiensis*. Various forms of skeletal spicules.—From Haslemere, Haldon; near Warminster. × 40 diameters.

Figs. 3, 4–4*d*. *Chenendopora*, sp. Skeletal spicules probably of more than one species.—Blackdown, Tilburstow Hill, near Warminster. × 60 diameters.

Figs. 5, 5*a*, *b*. *Ragadinia*, sp. Skeletal spicules.—Haslemere, near Warminster. × 60 diameters.

Figs. 6, 6*a–f*. *Siphonia*, sp. Skeletal spicules probably of different species.—Blackdown, near Warminster. × 60 diameters.

Figs. 7, 7*a*, *b*. Fragments of the skeletal mesh of a species of Hexactinellid.—Haslemere. × 60 diameters.

Fig. 8. Fragment of the skeletal mesh of another species.—Sevenoaks. × 60 diameters.

Fig. 9. Fragment of the skeletal mesh of another species in which the spicular nodes are octahedral.—Merstham. × 60 diameters.

Figs. 10, 10*c*. *Stauractinella*, sp.—Blackdown, Merstham. × 60 diameters.

Figs. 11, 11*a*. *Gomphites Parfitti*, CARTER.—Blackdown, Haldon. × 60 diameters.

Fig. 12. *Acerate spicule*.—From near Warminster. × 560 diameters.

Fig. 13. An imperfect spicule, the walls of which have been partially dissolved away, whilst the infilled interior canal has remained intact.—From Blackdown. × 40 diameters.

Figs. 14, 14*a*. The infilled canals of a spicule of *Geodites* and one of *Pachastrella*, which have remained after the walls of the spicule have been entirely dissolved away.—From Chert, Penzlewood. × 40 diameters.

Figs. 15, 15*e*. Residuary spicules, in which the colloidal silica has been removed, and the form of the spicule is retained in glauconite or allied silicate. These spicules are frequently contracted and distorted in a peculiar manner.—From Ventnor, and near Warminster.

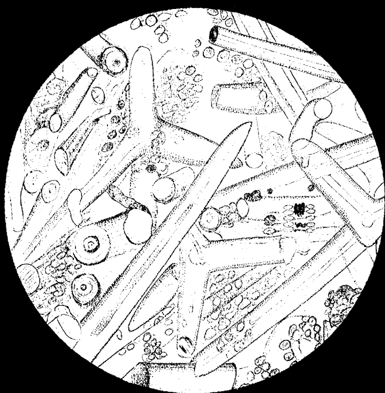
Fig. 16. A spicule of *Geodites*, in which the outer walls have been removed, and the infilled canal is surrounded by discs or globules of colloid silica.—From siliceous material in cavities in chert, near Warminster. × 150 diameters.

Fig. 17. A transverse microscopic section of a spicule in which the silica is crystalline and exhibits a radiated fibrous structure.—From chert at Petworth. × 150 diameters.

Figs. 18, 18*b*. Free discs or globules of colloidal silica.—From soft malm rock at Farnham. × 560 diameters.

Figs. 19, 19*e*. Discs or globules of colloidal silica, showing an indefinite nucleus, and faintly-marked radiating striæ. In 19*d*, *e*, the radiations start from a central point.—From loose powdery material in cavity in chert, near Warminster. × 560 diameters.

Fig. 20. A single coccolith from the Atlantic ooze for comparison with the siliceous globules. × 560 diameters.



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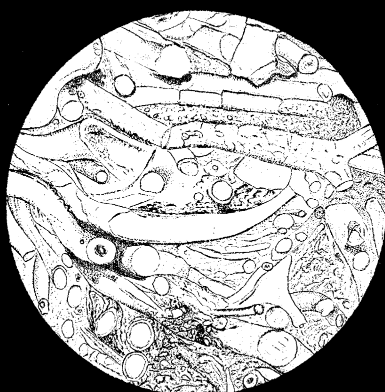

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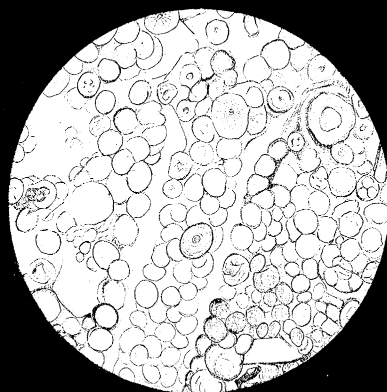

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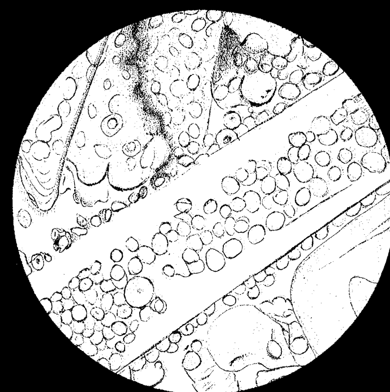

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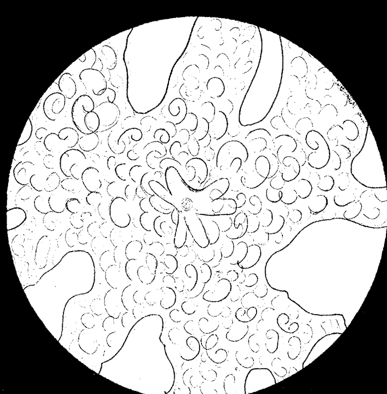

8 x 150

9 x 560.

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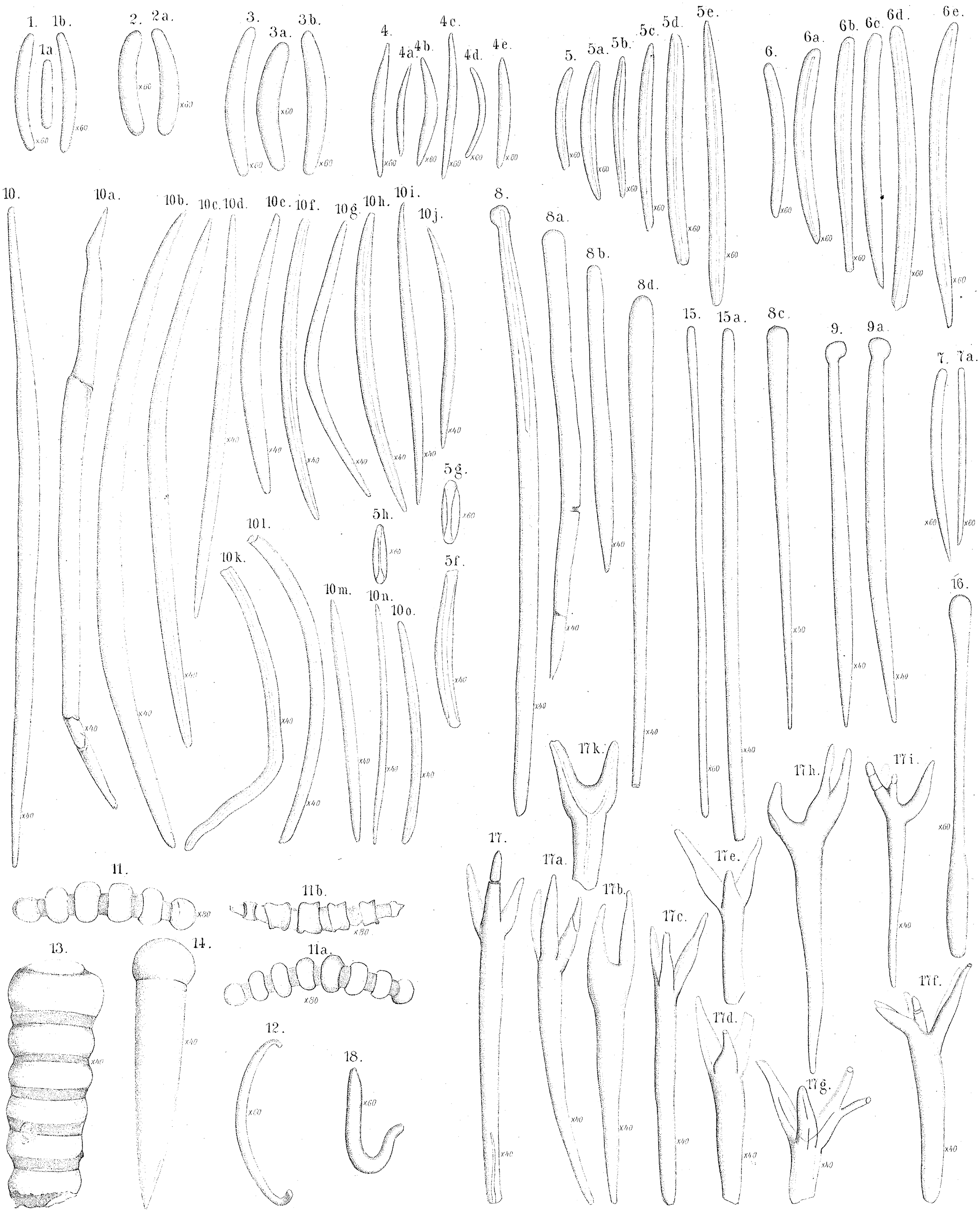

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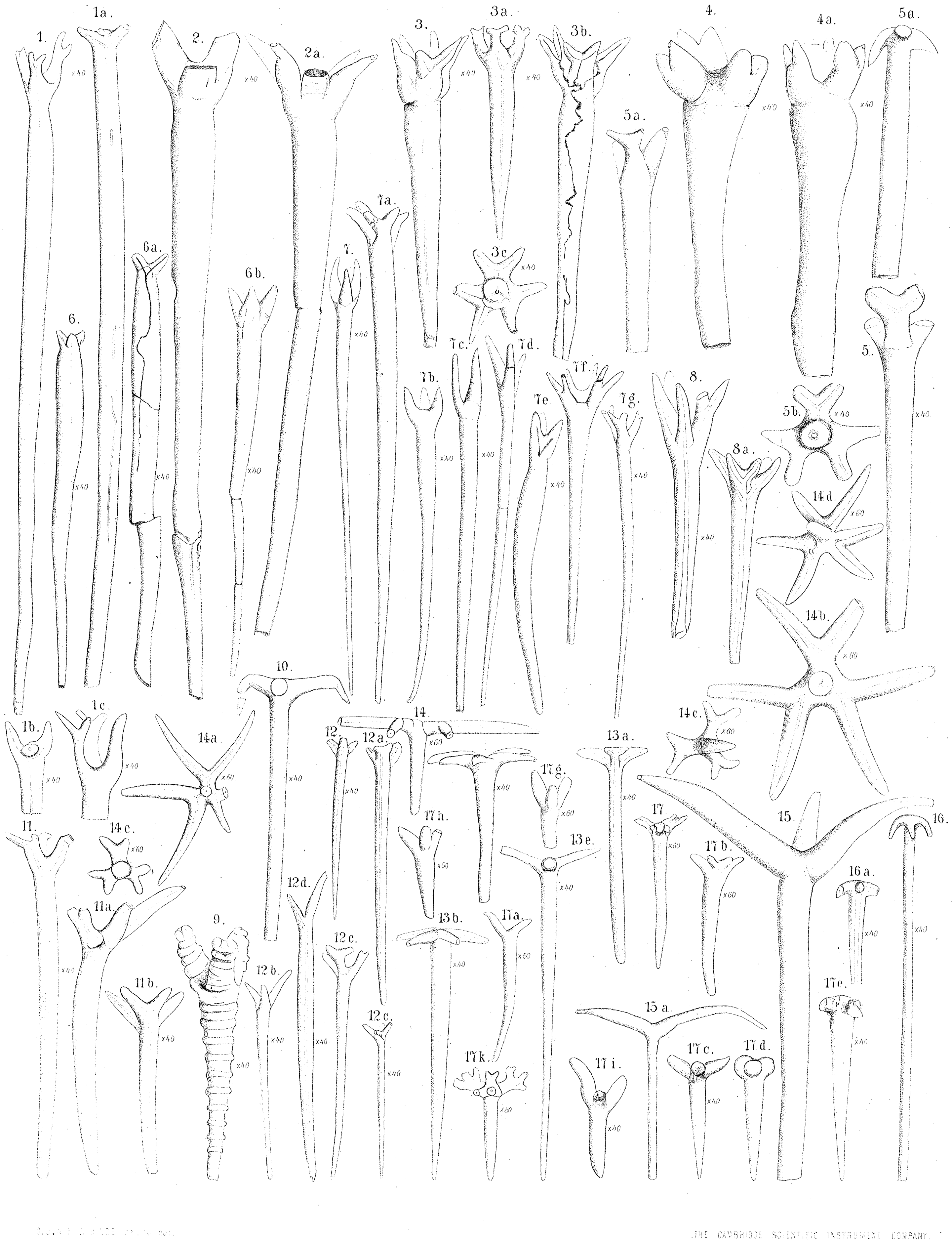
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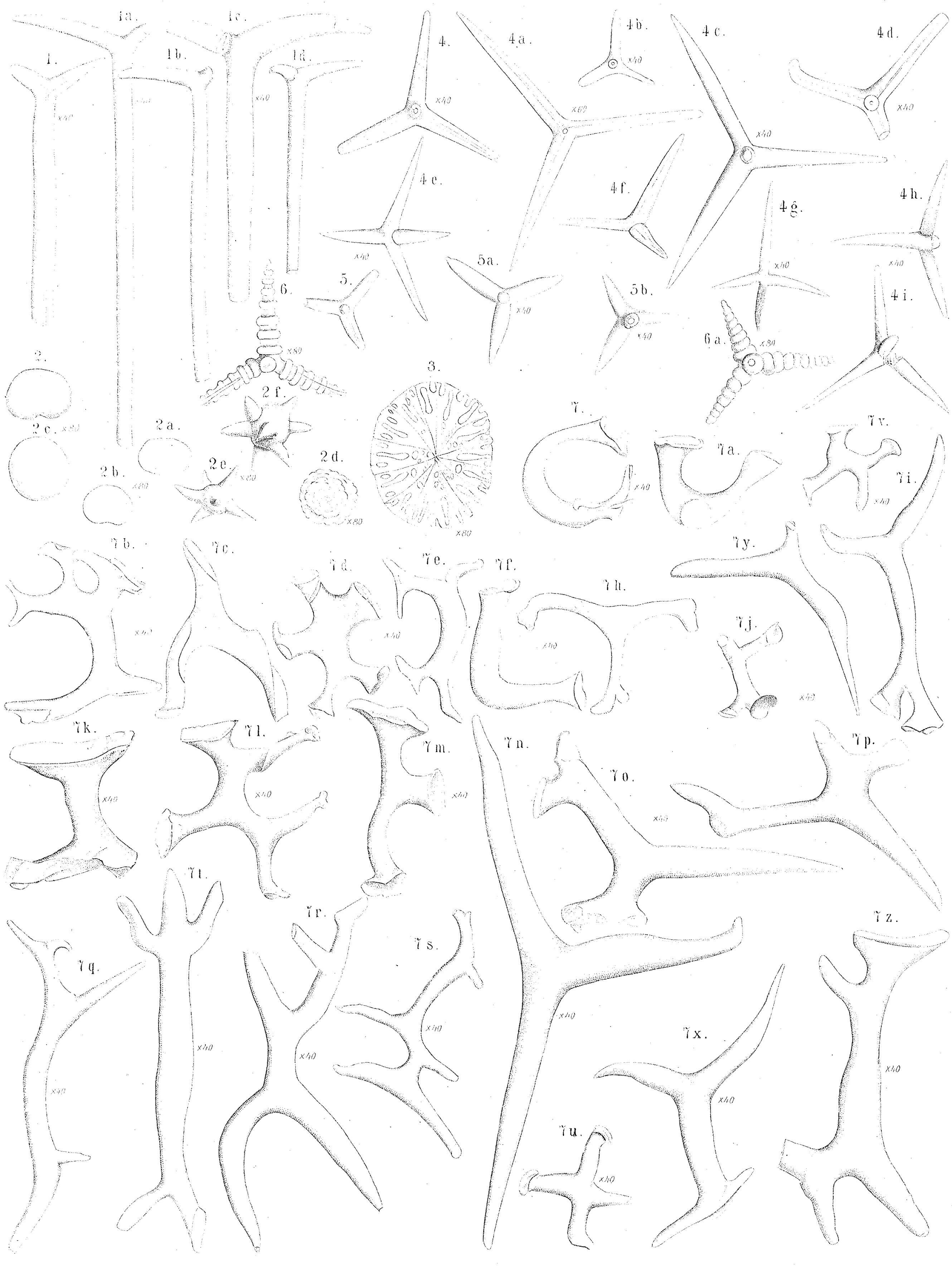

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All × 60.

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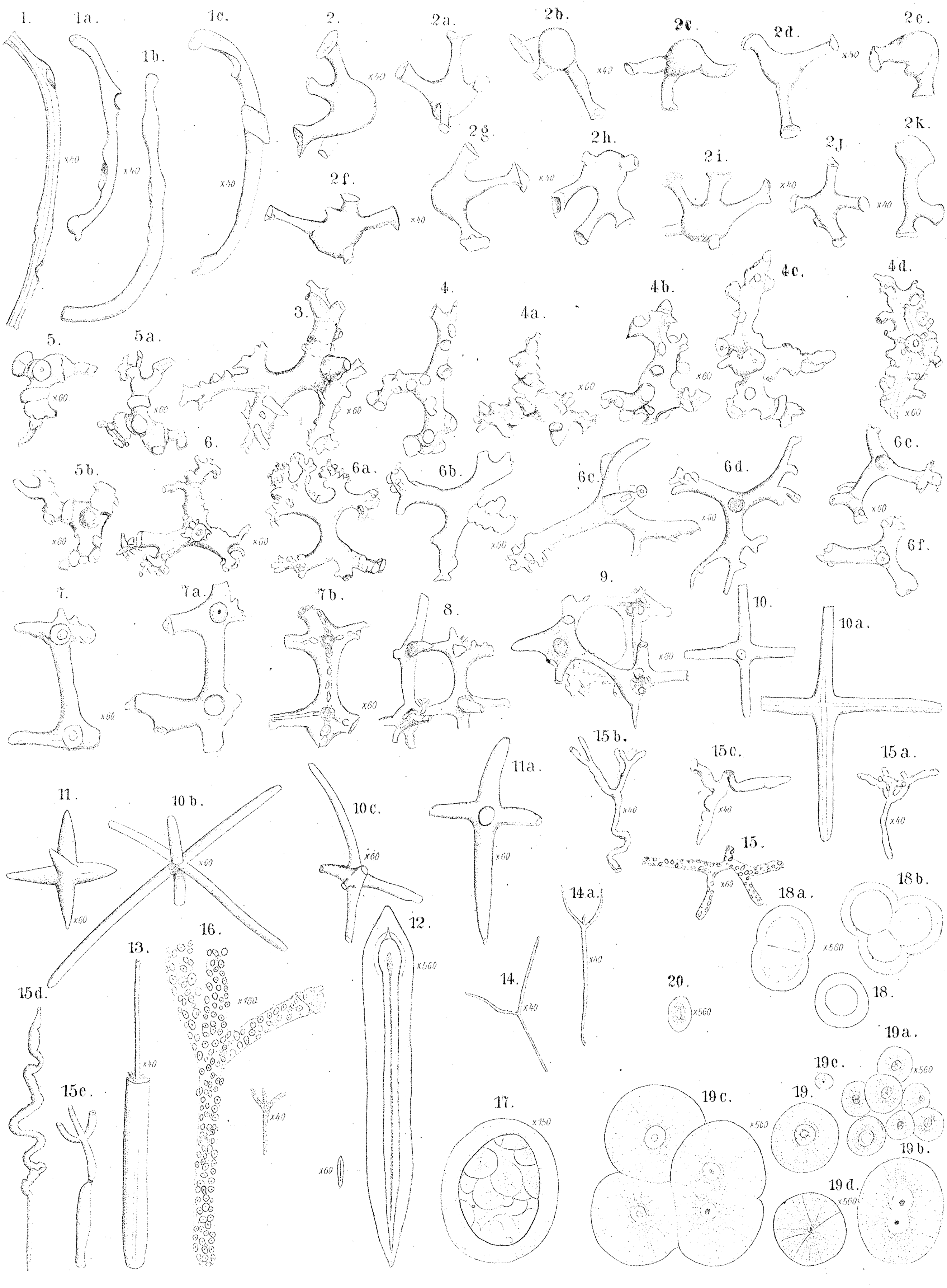

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PLATE 40.

Fig. 1. Microscopic section of a sponge-bed in the upper greensand at Warminster, showing entire and fragmentary spicules of colloid silica, inclosed in a matrix of transparent chalcedonic silica. Colloid silica in the globular form is also present. ×40 diameters.

Fig. 2. Microscopic section of a nodule from the upper greensand firestone at Godstone, filled with spicules of colloid silica in a siliceo-calcareous matrix. ×40 diameters.

Fig. 3. Microscopic section of chert from the upper greensand at Penzlewood, showing spicules and spicular canals of chalcedonic and crystalline silica, in a matrix of the same material. ×40 diameters.

Fig. 4. Microscopic section of a sponge-bed in the lower greensand at Tilburstow Hill, showing spicules replaced by crystalline calcite, inclosed in a matrix of granular calcite. ×40 diameters.

Fig. 5. Microscopic section of the malm rock from Merstham, showing a portion of a sponge-spicule in which the silica is in the globular form. The matrix largely consists also of colloid globular silica, with mica scales, grains of glauconite, and a small proportion of chalcedonic silica. ×150 diameters.

Fig. 6. Microscopic section of a sponge-bed in the upper greensand at Warminster, showing a portion of a sponge-spicule, the central part of which consists of colloid silica in a globular form, whilst the exterior is of chalcedonic silica. ×150 diameters.

Fig. 7. A fractured surface of the upper greensand "malm" at Merstham, showing the empty casts of spicules in a matrix of globular silica. ×40 diameters.

Fig. 8. A portion of a sponge-spicule from Warminster, in which the colloid silica is traversed by curved lines. ×150 diameters.

Fig. 9. A microscopic section of a portion of another spicule, still further magnified, in which the lines appear as incomplete elliptical rings with smooth rims. ×560 diameters.

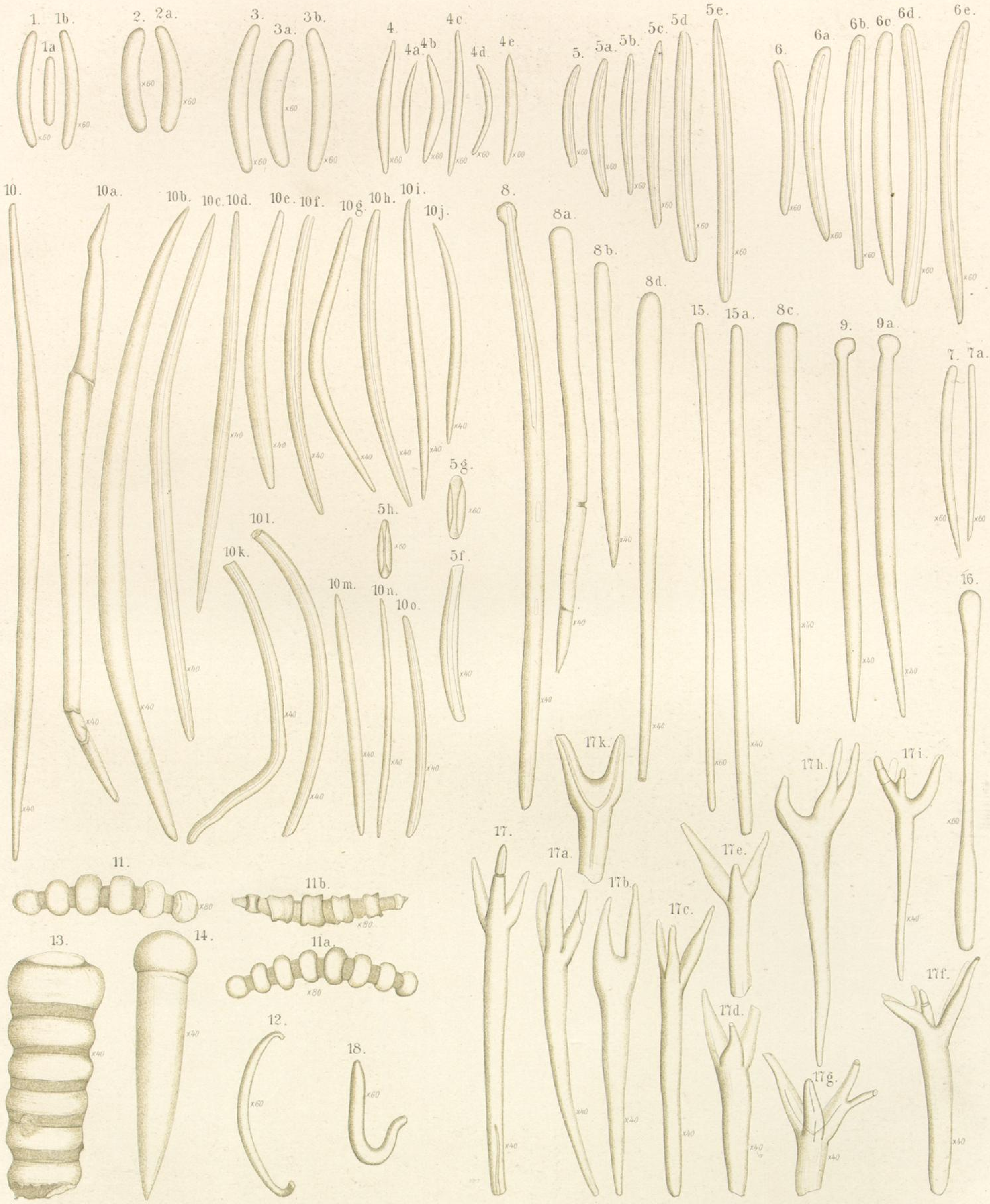

PLATE 41.

Figs. 1, 1*a*, *b*. *Reniera gracilis.*—Haslemere, Blackdown. ×60 diameters.

Figs. 2, 2*a*. *Reniera obtusa.*—Blackdown. ×60 diameters.

Figs. 3, 3*a*, *b*. *Reniera cucumis.*—Near Warminster. ×60 diameters.

Figs. 4, 4*a–e*. *Reniera Zitteli*, Počta.—Haslemere, Blackdown. ×60 diameters.

Figs. 5, 5*a–f*. *Reniera truncata.*—Near Warminster. ×60 diameters.

Figs. 5*g–h*. *Reniera truncata?* Immature spicules in which the canal remains open throughout its length.—Near Warminster. ×60 diameters.

Figs. 6, 6*a–e*. *Axinella dispersa.*—Blackdown; near Warminster, Merstham. ×60 diameters.

Figs. 7, 7*a*. *Axinella gracilis.*—Haslemere, Blackdown. ×60 diameters.

Figs. 8, 8*a–d*. *Axinella stylus.*—Haslemere, Blackdown. ×40 diameters.

Figs. 9, 9*a*. *Spirastrella neocomiensis.*—Haslemere. ×60 diameters.

Figs. 10, 10*a–o*. *Geodites.* Acuate spicules of different forms and dimensions belonging to various species.—Haslemere, Blackdown, Haldon; near Warminster, Merstham. ×40 diameters.

Figs. 11, 11*a-b*. *Monilites Haldonensis*, Carter.—Blackdown; near Warminster ×80 diameters.

Fig. 12. *Esperites Haldonensis*, Carter.—Blackdown. ×60 diameters.

Fig. 13. *Geodites Wrightii.* Acuate spicule, fragmentary. ×40 diameters.

Fig. 14. *Dirrhopalum neocomiensis.*—Haslemere. ×40 diameters.

Figs. 15, 15*a*, 16. *Pachymatisma? virga.*—Blackdown, Haldon. 15*a*, ×40 diameters, figs. 15, 16, ×60 diameters.

Figs. 17, 17*a–k*. *Geodites Carteri.* Zone spicules, showing various modifications of the head rays. In figs. 17*b*, *k*, only two of the rays are developed.—Haslemere, Blackdown. ×40 diameters.

Fig. 18. *Hamate spicule.*—Haslemere. ×60 diameters.

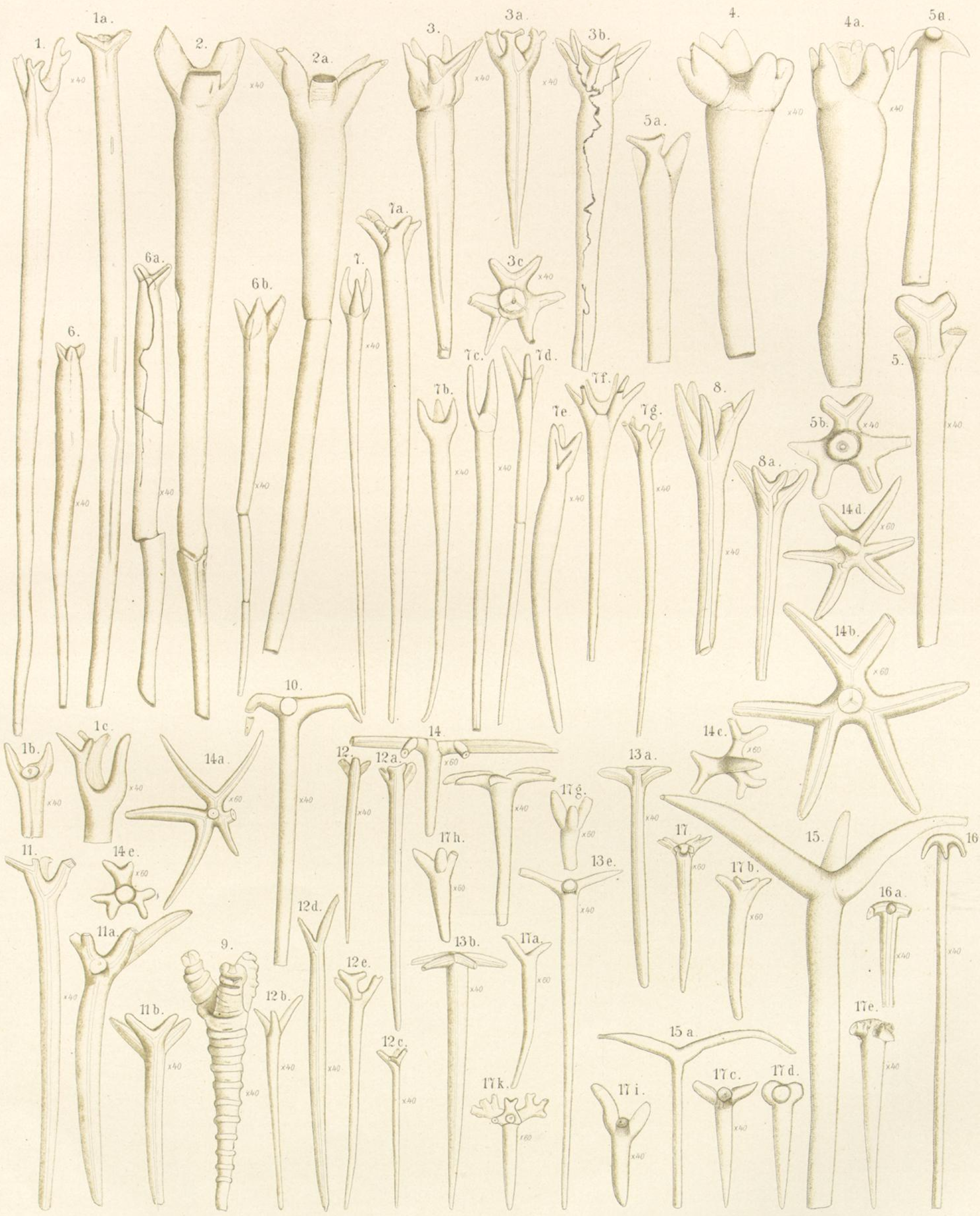

PLATE 42.

Figs. 1, 1*a–c*. *Geodites prælongus.* Zone spicules with simple and bifurcate head-rays. —Haslemere, Sevenoaks. ×40 diameters.

Figs. 2, 2*a*. *Geodites robustus.* Zone spicules.—Haslemere. ×40 diameters.

Figs. 3, 3*a–c*. *Geodites audax.* Zone spicules. Fig. 3*b* shows the peculiar manner in which the infilled axial-canal has been contorted and displaced. Fig. 3 is the head of a spicule seen from beneath.—Haslemere. ×40 diameters.

Figs. 4, 4*a*. *Geodites obtusus.* Zone spicules, the shafts incomplete.—Sevenoaks. ×40 diameters.

Figs. 5, 5*a–c*. *Geodites politus.* Zone spicules and anchor spicule (5*c*.)—Merstham, Folkestone. ×40 diameters.

Figs. 6, 6*a*, *b*. *Geodites pusillus.* Zone spicules.—Haslemere. ×40 diameters.

Figs. 7, 7*a–g*. *Geodites Haldonensis*, Carter. Zone spicules with variously modified head-rays.—Blackdown. ×40 diameters.

Figs. 8, 8*a*. *Geodites divergens.* Zone spicules with very prominent canals.—Near Warminster. ×40 diameters.

Fig. 9. *Geodites Wrightii.* Zone spicule, moniliform.—Haslemere. ×40 diameters.

Fig. 10. *Geodites deflexus.* Zone spicule, shaft incomplete.—Blackdown. ×40 diameters.

Figs. 11, 11*a*, *b*. *Geodites divergens.* Zone spicules.—Near Warminster. ×40 diameters.

Figs. 12, 12*a–e*. *Geodites gracilis.* Slender zone spicules.—Blackdown; near Warminster, Merstham.

Figs. 13, 13*a–c*. *Geodites planus.* Zone spicules with horizontally extended head-rays. Haldon; near Warminster. ×40 diameters.

Figs. 14, 14*a–e*. *Stellettites?* sp. Zone spicules, with reduced shaft and horizontally extended head-rays.—Blackdown; near Warminster, Merstham. ×60 diameters.

Figs. 15, 15*a*. *Tethyopsis Haldonensis*, Carter. Zone spicules.—Blackdown, Haldon. ×40 diameters.

Figs. 16, 16*a*. *Geodites Haldonenis*, Carter. "Anchor" spicules, shafts incomplete. —Haldon, Penzlewood. ×40 diameters.

Figs. 17, 17*a–k*. Small trifid spicules of different species. Figs. 17, 17*a*, *b*, young spicules of *Geodites.* ×60 diameters. Figs. 17*c*, *d*, *e*, allied to *Pachastrella.* Figs. 17*g*, *h*, *i*, spicules replaced by glauconite. Fig. 17*k*, dermal spicule of lithistid. ×60 diameters.—Blackdown, Warminster, Merstham, Ventnor.

PLATE 43.

Figs. 1, 1*a–d*. *Tethyopsis Haldonensis*, CARTER.—Blackdown. ×40 diameters.

Figs. 2, 2*a–f*. *Geodites*. Globate and globostellate spicules of the dermal layer of various species.—Haslemere, Blackdown, near Warminster. ×80 diameters.

Fig. 3. *Stellettites callodiscus*, CARTER. Spicule of the dermal layer.—Near Warminster. ×80 diameters.

Figs. 4, 4*a–i*. *Pachastrella Haldonensis*, CARTER. Four-rayed spicules of the skeleton. Blackdown; near Warminster, Merstham. Fig. 4*a*. ×60 diameters; the others ×40 diameters.

Figs. 5, 5*a*, *b*. *Pachastrella Carteri*.—Haslemere, Blackdown, Merstham. ×40 diameters.

Figs. 6, 6*a*. *Pachastrella quadriradiata*, CARTER.—Blackdown, near Warminster. ×80 diameters.

Figs. 7, 7*a–z*. *Doryderma*. Spicules of various forms belonging to the body and stem of different species of this and allied genera of the megamorina family of lithistidæ.—Haslemere, Blackdown, Haldon, near Warminster, Merstham. ×40 diameters.

PLATE 44.

Figs. 1–14. Various forms of spicules of the dermal layer, probably belonging to different species of tetracladine lithistidæ, of the genera *Siphonia*, *Hallirhoa*, *Ragadinia*, &c.—From Haslemere, Blackdown, Haldon, near Warminster, Merstham. All drawn by means of the camera lucida to the same scale of 60 diameters.

Figs. 15, 15*a*. *Discodermia sinuosa*, Carter. Spicules of the dermal layer of this existing species, for comparison with those of the fossil lithistids. From the Gulf of Manaar. Drawn from examples of the typical species, kindly presented to the Author by Mr. H. J. Carter, F.R.S. × 60 diameters.

PLATE 45.

Figs. 1–1*c*. *Carterella*, sp. Skeletal spicules.—From near Warminster. ×40 diameters.

Figs. 2–2*k*. *Mastosia neocomiensis*. Various forms of skeletal spicules.—From Haslemere, Haldon; near Warminster. ×40 diameters.

Figs. 3, 4–4*d*. *Chenendopora*, sp. Skeletal spicules probably of more than one species.—Blackdown, Tilburstow Hill, near Warminster. ×60 diameters.

Figs. 5, 5*a*, *b*. *Rayadinia*, sp. Skeletal spicules.—Haslemere, near Warminster. ×60 diameters.

Figs. 6, 6*a–f*. *Siphonia*, sp. Skeletal spicules probably of different species.—Blackdown, near Warminster. ×60 diameters.

Figs. 7, 7*a*, *b*. Fragments of the skeletal mesh of a species of Hexactinellid.—Haslemere. ×60 diameters.

Fig. 8. Fragment of the skeletal mesh of another species.—Sevenoaks. ×60 diameters.

Fig. 9. Fragment of the skeletal mesh of another species in which the spicular nodes are octahedral.—Merstham. ×60 diameters.

Figs. 10, 10*c*. *Stauractinella*, sp.—Blackdown, Merstham. ×60 diameters.

Figs. 11, 11*a*. *Gomphites Parfitti*, CARTER.—Blackdown, Haldon. ×60 diameters.

Fig. 12. *Acerate spicule*.—From near Warminster. ×560 diameters.

Fig. 13. An imperfect spicule, the walls of which have been partially dissolved away, whilst the infilled interior canal has remained intact.—From Blackdown. ×40 diameters.

Figs. 14, 14*a*. The infilled canals of a spicule of *Geodites* and one of *Pachastrella*, which have remained after the walls of the spicule have been entirely dissolved away.—From Chert, Penzlewood. ×40 diameters.

Figs. 15, 15*e*. Residuary spicules, in which the colloidal silica has been removed, and the form of the spicule is retained in glauconite or allied silicate. These spicules are frequently contracted and distorted in a peculiar manner.—From Ventnor, and near Warminster.

Fig. 16. A spicule of *Geodites*, in which the outer walls have been removed, and the infilled canal is surrounded by discs or globules of colloid silica.—From siliceous material in cavities in chert, near Warminster. ×150 diameters.

Fig. 17. A transverse microscopic section of a spicule in which the silica is crystalline and exhibits a radiated fibrous structure.—From chert at Petworth. ×150 diameters.

Figs. 18, 18*b*. Free discs or globules of colloidal silica.—From soft malm rock at Farnham. ×560 diameters.

Figs. 19, 19*e*. Discs or globules of colloidal silica, showing an indefinite nucleus, and faintly-marked radiating striæ. In 19*d*, *e*, the radiations start from a central point.—From loose powdery material in cavity in chert, near Warminster. ×560 diameters.

Fig. 20. A single coccolith from the Atlantic ooze for comparison with the siliceous globules. ×560 diameters.