FOSSIL

SPONGE SPICULES

FROM THE

UPPER CHALK.

Found in the interior of a single flint-stone from Horstead in Norfolk

BY

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Preface.

In the following pages I have attempted to give a description of the forms and affinities of a number of sponge spicules which were present, with a number of other organic remains, detached and heterogenously mingled together, in the cavity of a single flint stone, from strata of the Upper Chalk Formation, at Horstead, a village but a few miles distant from the city of Norwich, England.

The way in which I met with the material which yielded these sponge spicules is as follows: Returning to my native city after an absence of several years during which I had studied the Palæozoic rocks of North America, my interest was naturally excited by the contrast between the chalk and the limestones of the older rocks, with which I had become familiar, and I determined to examine the numerous pits, as they are termed, in which sections of the chalk were exposed to view, in order to become farther acquainted with the strata and to collect fossils for future study. With this purpose I went one day to a pit at Horstead, but found on my arrival that some long time had elapsed since the chalk had been worked; for already the section was partly obscured by a talus of gravel which had fallen from the overlying beds of rolled and stratified flints, and by the crumbling of the chalk itself, so that the prospect of obtaining fossils did not seem very promising. A search among the débris yielded only two or three specimens of *Terebratula carnea*, a few more or less perfect examples of *Ananchytes ovatus*, and the very common *Belemnitella mucronata* which could be seen everywhere in the face of the section. I began to think that nothing more than these common everyday fossils of the chalk would be the result of my search, and was about quitting the quarry when I thought it worth while to observe more particularly the large variously shaped nodules of flint which had been left, strewn over the floor of the pit, after the removal of the soft chalk in which they had been imbedded. One of the larger of these flints, about a foot in diameter, had been splintered, apparently by the sharp frosts of the preceding winter, and presented, instead of a solid mass of stone as is usual with the majority of the nodules, a central cavity, which contained a quantity of material resembling fine flour in appearance and feel, and of a creamy-white tint. An examination with a hand-lens showed that this floury material abounded with minute fossils, more particularly sponge spicules. Feeling at once certain that I had fallen in with a rich prize, I spread out a newspaper which I had brought to wrap up my fossils, and carefully emptied into it the contents of the cavity, which may have weighed when moist about a couple of pounds. The cavity appeared to have been completely inclosed by the flint, which had thus hermetically sealed up in its interior and preserved unharmed from mechanical injury, a small portion of the mud of the Cretaceous ocean. In fact, this material promised to afford as good evidence of the kind and variety of the ocean life of that period, as the material dredged up from the bottom of the present seas, did of the existing fauna.

It was not until some time after that I had discovered this material, that I became aware that Mr. Joseph Wright, F. G. S. of Belfast had also, a few years previously, ascertained, that many of the flints in the chalk of the North of Ireland, contained deposits, similarly rich in fossils, and that he had published a list of those which he had discovered in the contents of these stones. As, however, it did not appear that these microzoa had been previously noticed in the chalk Flints of the East of England, a locality several hundreds of miles distant, and in strata now entirely discontinuous from the beds of the Irish chalk, I determined to work out the contents of my discovery for the sake of seeing how far the fossils from these two places agreed with each other and with those of the cretaceous strata of Germany and elsewhere. Further I hoped to be able to show the great variety of the various forms of life which in such a small quantity of material and from a single locality were mingled together in the mud of the Cretaceous ocean, and consequently I resolved to limit my investigation to the contents of this single hollow flint.

I prepared this flint meal, if thus it may be termed, by carefully washing away the finer particles; which reduced it when dry to about 3 or 4 ounces in weight. By this means the fossils were brought into a small compass, but even so, it involved pretty constant work for several weeks to look over and pick out, under a strong simple lens, the principal fossils from this residue; for every spicule, foramenifer and entomostracan shell had to be separated from the mass by means of a moistened hair and afterwards these specimens had to be classified and then mounted for microscopic examination. I found the larger part of the various forms in the first fortnight of working at the material, but as nearly every day after this my search was recompensed by finding one or two new objects, I continued at the work until I reasonably thought that I had obtained specimens of every form present in the deposit. The result far exceeded my anticipations. The variety of fossil forms, all microscopic in point of size, in this mere handful of material, and their beautiful state of preservation proved extraordinary. There were fossilized remains, entire or fragmentary, of Foramenifera, Sponges, Echinoderms, Annelids; also of Cirripedia, Ostracoda, Polyzoa, Brachiopoda, Lamellibranchiata and lastly, Fishes; but by far the larger part of the fossils, belonged to the foramenifera, sponges, and ostracoda.

It was a subject for consideration as to which of these three different groups of fossils should be first studied; but as it appeared that less was known of the sponge remains of the English Chalk than of the foraminifera and ostracoda of this formation, I made up my mind to investigate first the fossils of this class. In order however to be able satisfactorily to ascertain the affinities of these isolated spicules and morsels of sponge skeleton, I found that it would be necessary to compare them with the more or less perfect fossil sponges whose structure had been already determined and that the only collection of sponges which would afford this opportunity for comparison was that made by Professor Dr. Zittel of the Royal Palæontological Museum of Munich. — I therefore resolved to study my fossil spicules at Munich, and on my arrival in that city I obtained from Prof. Zittel not only the freest opportunities for examining the rich collection of sponges in the museum, as well as the numerous microscopical preparations which had been made to illustrate their minute structure, but at the same time received from him the most cordial support and assistance in the progress of my work, for which I desire to express my heartiest thanks. I am further indebted to Prof. Zittel for the gift of a small quantity of material, rich in sponge spicules, from the upper Cretaceous Formation of Coesfeld in Westphalia which yielded me a great variety of forms of great value, from their beautiful state of preservation, for comparison with those from Horstead.

The time involved in describing these sponge spicules has been greatly prolonged by the necessity of making micrometer measurements of all the forms, not only in order to be able to make comparisons of their dimensions with those of spicules described in other works, but also to be able to state the real size of these fossils and thus allow a true idea to be formed respecting them. I have stated the measurements in millimetres and decimal parts of the same, so as to avoid giving to those students of sponges who make use of this *scientific* scale, the inconvenient task, which I have myself experienced, of reducing into millimetres the fractional or decimal parts of the English inch, in which the measurements of these small objects have been expressed by most English authors who have described them.

For the faithful representations of these spicules, which are given in the accompanying plates, I am indebted to Herr Conrad Schwager, Assistant in the Palæontological Museum at Munich, who, at very short notice, kindly undertook the task of drawing and lithographing them. As far as possible the figures have been drawn to the same scale of 20 diameters, in order to enable theirhrelative dimensions to be appreciated. In a few instances, in which a larger scale has had to be adopted, a representation of the object is also given, where practicable, on the same scale as the other spicules. In comparing the figures given in these plates with those of similar spicules which are given in the beautiful illustrations of Prof. Zittel's work on Coeloptychium and in Mr. Carter's figures of the spicules from the Haldon Green Sand, it is very necessary to bear in mind the different scale to which these figures have been drawn. In Professor Zittel's work the detached spicules on the Plates IV-VII are represented one hundred times magnified, and thus five times larger than in my Plates, and the Haldon spicules are drawn to the scale of seventy-five diameters or three and a half times larger. Bearing this fact in mind it will be noticed that most of the spicules from the Horstead chalk are actually larger than those from Germany and the South-West of England. I may add that the accuracy of the drawings of the Horstead spicules is further assured by their having been done by means of the Camera lucida.

Palaeontological Museum Munich.
November 1880.

Fossil Sponge Spicules

FROM THE

UPPER CHALK.

Found in the interior of a single flint-stone from Horstead, Norfolk.

BY

GEORGE JENNINGS HINDE. F. G. S.

The sponge spicules herein described were obtained from the material contained in the interior of a nodular flint, about one foot in diameter, which had been imbedded in the strata of the Upper Chalk Formation at Horstead, near Norwich. — In the Chalk pits or quarries in this neighbourhood not only are the nodular flints arranged in horizontal layers coinciding wich the stratification of the Chalk but they are also disposed in vertical layers, and the nodules thus arranged vertically are often of much larger size as well as different in form to those of the horizontal beds. Many of these larger flints are more or less cylindrical and either hollow throughout like a tube or with a deep cup-shaped depression at one end which has led them to be compared with the large horny sponges called Neptune's cups, though there is no evidence to show that they are more allied to these sponges, beyond a rude resemblance in outer form, than the ordinary shapeless nodules of the horizontal layers. On account of their peculiar form, these cylindrical, partly hollow masses of flint have been termed pot-stones or paramoudras. They have by no means a general distribution in the upper chalk strata, though they are of frequent occurrence at Horstead and are also met with in many of the Chalk pits near Norwich, and they appear as well in the same geological formation in the North of Ireland. These paramoudras are more frequently hollow than the ordinary nodular flints though they do not uniformly contain the fine powdery material which was present in the specimen I met with, but occasionally, as noted by Sir Charles Lyell, they have an internal cylindrical nucleus of pure chalk much harder than the ordinary surrounding chalk and not crumbling to pieces like it when exposed to the winters frost. In common with the other chalk flints of this district the exterior surface of the paramoudras is white and rough, while the interior is of a dark tint.

The particular specimen which yielded me the fossiliferous powder was about a foot in diameter and more spheroidal than the generality of the potstones. The manner in which the interior cavity became inclosed may be understood by supposing that the process of the deposition of the silica, by which the ordinary cup-shaped paramoudras were formed, was continued further, until the cup was arched over with a solid layer of flint, and thus the soft incoherent ooze included within was preserved safely from the effects of all further mechanical influence. Without entering here into the vexed question about the formation of the flints in the chalk, it may be as well to notice that the beautifully perfect state of preservation of the various delicate fossil organisms in the interior of this flint, when compared with the nearly complete obliteration of their structures in the enveloping chalk points to the conclusion, that the period in which the flints were formed must have been previous to that consolidation of the mass of the chalk by which the smaller fossils were mostly destroyed. The flint powder or flint meal which was preserved in the cavity of this flint, like the ashes of the dead in a funereal urn, had the appearance of a very fine flour of a creamy yellow tint, thus differing but slightly from the soft earthy white chalk in which the flints are here imbedded. The *finest* portions of the flint-meal, under high powers of the microscope were seen to be composed either of amorphous particles or fragments with a rounded outline, probably portions of the chambers of foramenifera. Besides these, there were a few straight rod-like particles, which may have been derived from sponge spicules but I could not detect any indications of the presence of coccoliths. After washing away the finer particles, the residue consisted, almost exclusively, of the entire and fragmentary skeletons of foramenifera, sponges and entomostraca, with a scanty intermixture of the remains of other organisms. There were but very few free, minute, mineral particles in the deposit and these, so far as I could judge, were iron pyrites. On subjecting a portion of the material to the action of Nitric acid, and heating; there was at first a certain amount of effervescence, but the result proved that only a small portion of the material was dissolved by the acid, and that the greater part, including fossil shells, which, like those of the foramenifera, were calcareous in their original structure, had now become either wholly or in part silicified. The material itself, previously of a creamy yellow tint became, after treatment with the acid, of a snowy whiteness. Being desirous of ascertaining the extent to which the different fossils were affected by the acid, I tried examples of different forms separately with the following results;

1st Sponge spicules. These were not perceptibly affected by the acid and retained the same optical appearances both before and after treatment.

2nd Foramenifera. The shells, previously opaque, or merely translucent by transmitted light, and white by reflected light, became as transparent as glass and the walls appeared reduced to great thinness.

3rd Entomostraca. A somewhat similar change was effected in the shells of these animals as in those of the foramenifera, but the residual siliceous shell was thicker and less transparent.

4th Echinoderms. Small fragments of shell of these organisms were nearly entirely dissolved by the acid leaving only a slight amorphous residue.

5th Mollusca. Detached prisms of the shells of Inoceramus which were very numerous in the deposit, were strongly attacked by the acid and completely dissolved, but very minute shells of a species of Ostraea though attacked by the acid yet retained the form of the shell perfect in silica.

6th Fish-scales. These were slowly but completely dissolved.

7th Coprolites. Small cylindrical pellets most probably coprolites, were readily attacked by the acid and dissolved with the exception of a residual reddish flocculent sediment.

It will thus be seen that the degree, in which the various fossils were silicified and suffered alteration in their originally calcareous structure, varied considerably in amount; that whilst the foramenifera and entomostraca became so infiltrated with silica as to retain the perfect form of their shells in this mineral, others, like the prisms of Inoceramus, though exposed to the same influences, had completely retained their normal condition.

Structure of the Sponge Spicules.

The Sponge spicules of this deposit, including under this term the individual siliceous bodies of exceedingly varied forms, which, either disconnected or attached together, form the skeletal support of the living organism, are exceedingly numerous, and with the exception of a few small fragments of the skeleton net-work of the Lithistidae and Hexactinellidae are isolated from each other. Seen under a low power and by reflected light the spicules with few exceptions have a complete outline and an aspect like that of ground glass. When mounted in Canada Balsam and examined by means of a higher power with transmitted light, the surface of the spicules appears to be rough, and pitted all over with small depressions, which in some examples are so strongly marked as to give a reticulated aspect to the surface. In the larger spicules the erosion which has produced the pitted surface has not affected the form of the spicule, but in the smaller and more delicate spicules, it has almost eaten through the spicule and rendered it, particularly near the extremities, very rough and jagged. As will be readily understood, the delicate spines with which the spicules of both fossil and existing sponges are frequently adorned, would be the first to be destroyed by the erosive action and still readier would the minute flesh-spicules be dissolved by it, so that no expectation could be entertained ot discovering these microscopic bodies in the material. The interior of the spicules shows numerous minute ill-defined brownish spots from which, as from so many centres, extremely small radial fibres extend in all directions. When examined by polarised light these fibrous rays display prismatic tints similar to those peculiar to chalcedony, thus showing that the silica in these spicules, has been changed from the colloidal condition of the mineral to the crypto-crystalline state of chalcedony. In the brownish spots in these spicules the prismatic tints are far less clearly displayed than in the fibrous portions. There are however other spicules in the material, belonging to various genera of sponges, which, instead of the dull glassy aspect, common to the great majority of these sponge remains, exhibit, by reflected light, a white snowy appearance, and when these snowy-white spicules are mounted in Canada balsam they display a thin outer coating of silica, which is transparent and also gives prismatic tints in the same manner as the ordinary spicules; within this, however, the silica is of a brownish granular aspect as if intermingled with ochreous particles, and does not give the prismatic tints under polarised light. The boundary between the brownish, apparently amorphous, silica in these spicules and the outer layer of Chalcedonic silica is very irregular, the one form apparently gradually merges into the other. It would seem that the silica in these examples, to a certain extent retained the characters of the originally colloidal silica of the spicules, whilst in the majority of the spicules in this material the metamorphosis of the silica had been extended further, until, with the exception of a few minute spots, the whole of the spicule had become changed into chalcedony. I may remark here, that so distinctly are the sponge spicules in this deposit shown by polarized light, that, in a small quantity of the flint-meal mounted in balsam, the minutest particle of spicule at once reveals itself by the prismatic tints which it exhibits, and I availed myself of this fact to determine the characters of some delicate lamina, which otherwise had the appearance of small portions of shell.

Not only has chalcedonic silica thus replaced the original colloidal silica in these spicules, but it has also, in the majority of instances, completely filled their interior canals, so that the spicules now appear solid throughout. Here and there however, spicules are met with, in which the canals are either wholly or in part preserved, but even in these instances they do not present the form of regular even tubes as in recent sponge spicules, but are abnormally and irregularly enlarged. Sometimes the canal yet extends throughout the length of the spicule, in other instances only a small part in the upper and thicker part of the spicule is to be seen. The canal, where retained, appears to be hollow, or infiltrated more or less with ochreous particles, and an example of this latter in which the canal is shown as a thin black tube extending along the central axis of the spicule is given on Plate V. fig. 30.

The present condition of the sponge spicules in the interior of this Horstead flint, thus shows a great alteration from their original condition. The smooth surfaces have become rough and eroded, the delicate spines have been dissolved away, and the amorphous silica is, for the most part, changed into crypto-crystalline chalcedony, which has also filled up and obliterated the interior canals. They thus furnish corroborative evidence of the instability of silica in its amorphous condition, and show that even where sponge spicules have been preserved tolerably complete in outer form yet their interior structure has been considerably modified. A similar change has also been noticed in the mineral condition of sponge spicules from other formations and localities. Thus Mr. Carter (An. and Mag. Nat. Hist. S. 4, Vol. 7, p. 112 et seq.) describes the spicules from the upper Greensand of Haldon near Exeter as being changed into chalcedony and having their surfaces eroded and the interior canals partly or wholly destroyed. The condition of the spicules from the flints of the North of Ireland, discovered by Mr. Wright, is not stated (List. of the Cretaceous Microzoa of the North of Ireland), but as the calcareous remains in these flints were infiltrated with silica, like those from Horstead, it may be inferred that the sponge spicules had been altered in a similar manner. I find too, that a similar alteration in the mineral condition of the silica has taken place in sponge spicules forming thin beds in the Lower Green Sand (Neocomian) in Surrey, which I have lately discovered. This change, however, in the condition of spicules, occurring, as in the instances mentioned, detached and scattered in the interior of flints or in beds of Green sand, does not appear to have taken place invariably, and a noted exception is seen in spicules found in connection with Coeloptychium in the upper Chalk Strata of Coesfeld in Westphalia. These have been described and figured by Professor Zittel in his work on Coeloptychium (Abh. d. k. Ak. d. Wiss. XII Bd., III. Abth.) and present a great contrast to the spicules from Horstead. The Coesfeld spicules have, by reflected light, a smooth, white porcellanic aspect, and when mounted in Canada balsam, their outlines under the microscope are still seen to be smooth, and the interior canals are equally as perfect as in recent spicules. Another feature of the little change which these spicules have suffered, is shown by their being neutral to polarised light, thus proving that the silica still retains its colloidal condition, although it has lost that beautiful clear glassy appearance which characterizes the spicules of recent sponges. The state of preservation in which these Coesfeld spicules are found may, however, be regarded as exceptional, in the majority of instances in which detached spicules have been noticed the silica appears to be now in the form of Chalcedony.

As I have already mentioned, the eroded condition of the larger spicules plainly indicates that none of those much smaller forms which have been termed flesh-spicules, have stood any chance of being preserved, and therefore, for the purposes of classification, the characters of the skeleton spicules will alone have to be relied upon. Of these I separated some thousands of specimens and they present the most manifold varieties both of form and size. In dimensions they vary between 0.18 mm., the diameter of small globo-stellates, and the comparatively great dimensions of 8.77 mm., the length of the longest trifid spicules. The various forms comprise straight and curved cylindrical acerates, conical and fusiform acuates, a great variety of trifid spicules (i. e. those with an elongated shaft and a head of three rays); quadrifid spicules, globates and stello-globates, contorted skeleton spicules of Lithistids and free and combined six-rayed spicules. Besides these different forms of isolated spicules there are a few specimens in which small fragments of the mesh-work of the sponge, showing the spicules naturally attached together, have been preserved. A glance at the figures given in the different plates will better enable an idea to be formed of the great diversity presented by these spicules, mixed up together in the interior of this single flint, than can be conveyed by a mere verbal description.

In endeavouring to classify these, for the most part, isolated spicules, I have compared them with the valuable collection both of recent and fossil sponges contained in the Palaeontological Museum at Munich, (which was freely placed at my disposal for this purpose by Professor Zittel) and with the figures and descriptions of sponge spicules given by Carter, Zittel, Oscar Schmidt, Sollas, Bowerbank and other authors who have devoted attention to the microscopic structure of the sponge skeleton. The multitude of works and descriptions of both earlier and later writers on fossil sponges, which are mainly based on the outer form of the organism, leaving undescribed the character of the constituent spicules, were of no value to me whatever, since my material only consisted of the small bodies by whose combination the sponge itself is formed. It has been only within the last few years that the fundamental structure of sponges has been studied and the true character of the spicular skeleton recognized and made the basis of classification, and though very much remains to be done in this field of investigation, the knowledge which has been already obtained of the spicular structure of fossil sponges, mainly through the researches of Zittel, Carter, and Sollas, has made it possible in many instances, to determine the genus of sponges to which these isolated and scattered spicules belong. There are however several difficulties, in connection with the determination of the relationship of these detached spicules, which only allow an approximate conclusion to be made as to their affinities. One cause of this uncertainty arises from the fact that in the skeletons of both fossil and recent sponges, very many spicules get intermingled with the sponge, which have only found their way in the structure by mechanical means and are not integral portions of the organism, though they have frequently been mistaken for such, and have given rise to the belief that in the same sponge there could exist the most varied collection of spicules. Another difficulty is owing to the fact of the same form of spicule being common to several different genera of sponges so that it is quite impracticable to determine to which or how many of these genera the form may have belonged. In other sponges, there are six or seven different forms of spicule in the same species, of which one or two of the forms may be characteristic of the species, whilst the other spicules may be common to other species as well, so that, although all the different forms of spicule may be present in the material, there is no certainty that they have been derived from the same genus or species of sponge. The peculiar form and mode of attachment of the spicules of the Lithistid and Hexactinellid Sponges permits of a better identification of their spicules than in those of the Tetractinellid sponges, and in several instances the correspondence in form and size of the spicules is so close to that of sponges already determined, that no doubt can arise of their belonging to the same species. Under these circumstances I have arranged these spicules under the different genera with which they seemed to have the closest relationship, and in only a few exceptional cases in which the peculiar form or dimensions of the spicule rendered it highly probable that it belonged to some hitherto unrecognized sponge, have I ventured to give a name to it, to facilitate reference in the future.

Of the works which have already appeared on detached fossil sponge spicules to which I shall frequently have occasion to refer, the first is that of Mr. H. J. Carter, F. R. S. On Fossil Sponge Spicules of the Greensand compared with those of existing Species. (Annals and Mag. Nat. Hist. 1871, S. 4 Vol. 7, p. 112, Plates VII—X.) In this article, Mr. Carter gives an excellent description and figures of 76 different forms of detached spicules which were discovered in strata of the Greensand Formation (Cenomanien) at Haldon near Exeter, and shows their close relationship to existing sponges. Some of these Greensand spicules are identical in form with those from the Horstead flint and all of them are closely related, but there is not the variety of Lithistid and Hexactinellid spicules as at Horstead.

In 1873-4 Mr. Joseph Wright F G. S. of Belfast gave illustrations of 34 different forms of spicules which he had discovered in the interior of flints from the upper Chalk Formation in the North of Ireland. (A List. of the Cretaceous Microzoa of the North of Ireland. Belfast. Nat. Hist. Field-Club Report). The late Dr. Bowerbank drew up a report on these spicules but limited himself to giving them some very long names and indicating the resemblances of a few of them to existing genera. With hardly an exception, all these Irish Chalk specimens are present in the Horstead flint, but the sponges do not seem to be anything like so well represented in the Irish as in the Norfolk Chalk, though the material examined by Mr. Wright was collected from several localities, and appears to have been carefully searched.

Also in 1874, M. A. Rutot described and figured numerous forms of sponge spicules from Tertiary sands of the Etage Bruxellien in the neighbourhood of Brussels (Annales de la Société Malacologique de Belgique. Tome IX, 1874). M. Rutot believed that these spicules belonged to two sponges merely, though there is no doubt that several different genera are represented. A few of these Tertiary spicules are similar to those from the Horstead flint but so far as can be judged from the figures the majority of them are different forms.

In 1876 Professor Zittel figured numerous spicules which were from the Upper Chalk of Coesfeld and other places in Westphalia. (Ueber Coeloptychium. Abh. d. k. Ak. d. Wiss. XII. Bd. III. Abth.) From finding many of these spicules in close connection with the skeleton of Coeloptychium, Professor Zittel thought, previous to his later researches, that they might have belonged to that genus. With but few exceptions, the forms figured by Professor Zittel are found also in the

Horstead flint, and they are in a much more perfect state of preservation.

In describing these Horstead spicules, I propose to begin first with the simple uniaxial forms and then pass on to the quadriaxial spicules and the more complicated lithistid and hexactinellid forms; following the systematic arrangement which is given by Professor Zittel in his «Beiträge zur Systematik der Fossilen Spongien».

Monactinellidæ, *Zittel.*

To this order belong those sponges whose skeleton consist only of those spicules which possess a single unbranched interior canal. But as simple monaxial spicules are also common to other orders of sponges as well, the question of determining the proper relationship of these spicules, when detached, as in the specimens under consideration, is somewhat involved. As the only method available, I have compared the simple uniaxial spicules in this deposit with those which are present in recent and fossil sponges of the order, as well as with the uniaxial spicules which are found in connection with the distinctive spicules of Geodia and other genera, and I have come to the conclusion that the greater number of the uniaxial spicules in this deposit more probably belong to Geodia and thus formed part of the Skeleton Spicules of Tetractinellid sponges, under which I shall include them. Those which appear to have belonged to Monactinellid sponges are not very numerous.

Acuate Spicules.

(Plate I, figs. 10—15.)

Simple acuate spicules, somewhat resembling pins, but with less prominent heads, curved, thickest at one extremity and gradually tapering to the other, which in some instances is obtusely pointed. Originally smooth, though now with pitted surfaces. Canals obliterated. In one instance (fig. 11) there is a sharp bend in the upper portion of the spicule whilst the lower part is straight and pointed. The largest of these spicules is 2,9 mm. long by 0,13 mm. wide; the smaller form (fig. 12) is 0,94 mm. long by 0,067 mm. wide. In fig. 13, the head is much larger in proportion to the length; this spicule is 0,832 mm. long by 0,15 mm. wide. All the forms are rare.

Acuate spicules similar in form but usually so much smaller as to preclude a fair comparison are frequent in recent sponges from the Atlantic and have been placed by Mr. Carter under the genus Halichondria (Ann. and Mag. Nat. Hist. S. 4, Vol. XIV 1874, p. 16. Pl. XV, fig. 40 b, 41 b. — Vol. 18, Pl. XV. fig. 29). Oscar Schmidt also figures a similar form in *Plocamia gymnagusa* (Atlant. Spong. p. 62, Taf. 4, fig. 17b) and Sollas has also described like spicules in other species of the same genus (Ann. and Mag. Nat. Hist. July 1879 p. 44, Pl. VI, fig. 3). Acuate spicules but with more developed heads appear in the Haldon Green Sand (Ann. and Mag. S. 4, Vol. VII, Pl. X, fig. 77) and also from the upper Chalk at Coesfeld (Ueber Coelop. p. 37, Taf. V, fig. 1—10).

There are two other forms of acuate spicules, in which the thickest portion of the spicule is just below the head and the spicule itself is straight and pointed (Plate I, figs. 14, 15). The larger is 1,23 mm. long by 0,112 mm. wide, and resembles in form a spicule from Haldon (Ann. Vol. 7, Pl. X, fig. 78) and the smaller is 0,517 m.m. long by 0,56 mm. wide.

Reniera, sp.

(Plate I, figs. 18, 19, 22).

Spicules of a regular conical form, the thicker end evenly rounded and from this tapering either to a point or more frequently ending obtusely. In rare instances, the smaller end expands slightly, and the spicule becomes intermediate between a cone and a cylinder. Outer surface originally smooth. The interior canal is frequently preserved, it is of a conical form corresponding to the shape of the spicule; in some instances it extends but a short distance from the head, in others it is prolonged nearly to the point of the spicule. These conical spicules are very abundant and very regular in form. They vary in length between 0,495 mm. and 0,832 mm. and in width of the head or thickest portion between 0,135 mm. and 0,225 mm.

I have also found a single specimen of a spicule nearly alike in form to these small cones but characterized by the surface being completely covered with small blunt spines (fig. 22). No canal can be distinguished. The specimen is 0,45 mm. long and 0,157 mm. wide.

The only instance of spicules of this conical form, which I have met with, is given by Mr. Carter as a transitory stage of the dermal globular crystalloids of *Pachymatisma Johnstonia,* Bowerbank (Ann. Mag. Nat. Hist. S. 4, Vol. 4, p. 9, Pl. II, fig. 18 c). The resemblance is however merely in the outer form, for Mr. Carter states as regards these bodies, that on no occasion has he been able to detect a central cavity in any stage of their development, whereas the interior canal is clearly exhibited in the Horstead spicules. As regards their respective dimensions I am unable to make a comparison, for the scale to which Mr. Carter's figure has been drawn, is not stated. These conical spicules appear to be related to the cylindrical spicules present in some species of Reniera and I have therefore placed them provisionally under this genus.

These conical spicules have been found, though rarely, in the North of Ireland (Wright; op. cit. p. 88, Pl. II, fig. 3) and I have also discovered them in material from Coesfeld, given me by Prof. Zittel. The spinous form also is present in the Upper Chalk Strata of Coesfeld.

Reniera, sp.

(Plate I, figs. 16, 17).

Spicules of a cylindrical form, curved, uniform in calibre throughout and rounded at both ends. Exterior surface originally smooth. Canals obliterated, but in similar spicules from the Westphalian Chalk a simple cylindrical canal traverses the spicule. There are two well marked forms of these spicules; the one (fig. 16), longer and proportionally much thinner than the other, has a length of 0.517 mm. by 0,056 mm. The shorter (fig. 17) form, in some specimens almost kidney shaped, is 0,33 mm. long by 0,112 mm. wide. Specimens of both forms are not uncommon.

Spicules of existing sponges, nearly approaching in form to these, have been discovered by Mr. Carter in species of Reniera from the Gulf of Manaar; (An. and Mag. Nat. Hist. S. 5, Vol. 6, p. 478, Pl. V, fig. 18). Cylindrical spicules have also been figured by Oscar Schmidt in a sponge from the Atlantic, *Suberites arciger* (Atlant. Spong. p. 47, Taf. V, fig. 6). Cylindrical spicules similar in form but of larger size have lately been discovered by Mr. Carter in Irish Carboniferous strata (An. and Mag. S. 5, Vol. 6, p. 212, Pl. XIV, fig. 14). They are present also in the Chalk Strata of Coesfeld. (Ueber Coelop. p. 40, Taf. IV, figs. 38—43) and in the Green Sand at Haldon (An. and Mag. Nat. Hist. S. 4, Vol. 7 Pl. IX, fig. 53).

Scolioraphis? sp.

(Plate I, fig. 5).

Very elongated, sinuous spicules, apparently cylindrical, of the same thickness throughout their length, irregularly bent and fractured at their extremities. A central canal is exhibited in some specimens. The surfaces of these spicules are far more eroded than any others in this flint-meal, and forameniferal shells and other small objects frequently adhere to them, so that they have an altogether different aspect to any other of the sponge remains, and at first led me to doubt whether they were spicules, but the presence of the interior canal points them out to be such. With one exception, in which there is a slight tapering at one extremity, all these spicules terminate abruptly, as if broken off at their ends, and therefore may be regarded as incomplete. One of the longest of these fragmentary spicules is 5,175 mm. long by 0,225 mm. wide, others are only 0,135 mm. in width, but their outer surfaces are so eroded that originally they may have been considerably thicker. It is quite a matter of conjucture as to the sponge of which these were the skeleton spicules, as, so far as I am aware, no sponge with similar spicules has yet been described. In *Scolioraphis anastomans* Zittel (Studien über foss. Spong. p. 95, Taf. XII, fig. 1) there are also sinuous spicules, but they are provided with knobbed surfaces, and are much smaller than these from Horstead.

Order Tetractinellidae, Marshall.

The characteristic spicule of this division of sponges has four arms or rays, one usually much longer than the others, radiating from a centre. Each ray is provided with an interior canal which unites with those of the other rays and, where the rays are bifurcated, the canal is also bifurcated and a branch extends into each division. There are two principal forms in which these quadriaxial spicules may be divided. In one there is a great development of a single ray, which becomes an elongated gradually tapering shaft, pointed at one end, whilst from the other and usually the thickest portion of the shaft, there spring three short arms or rays in very varying directions; in some spicules prolonged backwards, fork like, nearly in a line with the shaft itself; in others, at varying angles between the perpendicular and horizontal; whilst in other spicules the rays curve backwards, in the direction of the point of the shaft, and become anchor-shaped. These three capitate rays vary, in different spicules, very much in their form and dimensions, some are very small, cylindrical and blunted, others, at the point of junction with the shaft, are as stout as the shaft itself and become gradually pointed, whilst in other spicules the head rays are largely developed, frequently accompained by a diminution of the shaft, which in the extreme forms is reduced to a small blunted process. Neither are the rays themselves uniform, very often one is longer or shorter than the others of the same spicule. Another feature of these capitate rays is that one or all of them may bifurcate and the divisions, like the simple rays, are often of unequal length. That this bifurcation of the capitate rays is only a further development of the growth of each ray and not characteristic of a particular form of spicule, is evident by the numerous examples in this flint meal, in which a gradual transition may be seen from specimens which have all the rays simple, to those in which one, two, and finally all three of the rays are bifurcated.

For this form of spicule in which the shaft is very prominent in relation to the head rays, as well as for those in which the shaft has been reduced, but can yet be recognized as distinct from the head rays, I propose to employ the term «*trifid*» spicule, and where the rays are simple, to denominate the spicule «*simple trifid*,» and where bifurcate, «*compound trifid.*»

The other main form of quadriaxial spicule has the four divisions or arms more or less like each other, so that it is not easy to determine which of them corresponds to the shaft of the trifid spicule. In a very few instances one of the arms of these spicules has been extended beyond the central point so that a five rayed spicule results. The arms of these four rayed spicules sometimes radiate from the centre at an equal angle from each other, but in other examples one arm is at a more or less open angle and occasionally nearly at a right angle to the other three arms. A few of these spicules also have a tendency to bifurcate. I propose to designate this form of spicule *simple* or *compound quadrifid* according as the arms are simple or bifurcate.

In addition to these trifid and quadrifid spicules, all or nearly all the sponges of this order have acerate spicules, often of two dimensions in the same species, and many have a surface layer of minute globate and globo-stellate spicules or small discoidal bodies.

All the different forms of spicules which have been recognized in existing sponges of this order; the globate, globo-stellate and discoid bodies forming the outer cortex; the trifid spicules of the *zone* supporting the crust; the acerate and quadrifid spicules of the *body*; and the anchoring spicules, are represented in the Horstead flint meal, and if we may judge by the relative number of the spicules, the Tetractinellid sponges must have far exceded the contemporary Lithistid and Hexactinellid sponges of the Chalk. In existing sponges of this order the skeleton spicules are distinguished by being much more robust than those of other types, and the same characteristic is displayed by the Chalk spicules.

As regards the acerate spicules which I regard as belonging to this group, there is no peculiarity by which those belonging to different genera can be distinguished, nor are the minute spheres, stellates and discs of much service either in this respect, but it is a question how far the different forms of trifid and quadrifid spicules, which compose the zone and body spicules of these sponges, may be representative of different species. According to Mr. Carter's descriptions of existing species of Geodia and Stelletta from the South coast of Devon, (An and Mag. Nat. Hist. S. 4, Vol. 7, p. 9, Pl. IV) from the Atlantic, (Vol. 18, p. 397, Pl. XVI); and also from the gulf of Manaar, (S. 5, Vol. 6, p. 485, Pl. V, VI), there are present in each species, in addition to the globate and stellate spicules, the large and small acerates, and the minute anchor-shaped trifid, a single form of large trifid which presents characters sufficient to distinguish it from the large trifids of other species. Dr. Bowerbank also figures a single large trifid as one of the characteristic spicules of Geodia Zetlandica (Monogr. Brit. Spong. Vol. III, p. 15, Pl. 7, fig. 6). On the other hand O. Schmidt in his descriptions of species of Geodia and Stelletta from the Adriatic (Spong. d. Adriat. Meeres 1862, p. 46, 49, 50, Taf. III, IV) represents two or three forms of large trifid spicules (Anker) in the same species and some of these appear common to two or more different species. It thus becomes very uncertain whether the numerous and very variable forms of large trifid spicules which are present in this flint-meal should be taken to indicate as many species of sponge, or whether two or three of different forms may have belonged to one and the same species. Even however, if we accept this latter view, it will be seen from the number of forms of these spicules, that a considerable number of species of this group lived together in the Cretaceous ocean. Before describing these trifid spicules in detail, I propose first to refer to the acerate spicules which probably accompanied them.

Acerate Spicules of Geodia and allied Genera.

(Plate I, figs. 1—3, 20, 21).

Comparatively large, simple, straight and curved spicules, which may be arranged under three different forms; First, Straight spicules (fig. 1) thickest in the centre and gradually tapering towards the pointed extremities; Second, Curved spicules (fig. 2) also pointed at both ends, and thicker in proportion to their length than the straight specimens; Third, Spicules of a rod-like character (fig, 5) nearly cylindrical or diminishing very gradually towards the extremities; I have found none of these latter retaining their ends perfect. Surface of these spicules apparently smooth originally. In none has the central canal been preserved. The shorter forms of these spicules measure 3,37 mm. long by 0,045 mm. wide, whilst the larger attain dimensions of 5,5 mm. in length by 0,135 mm. in width. Occasionally spicules of still larger dimensions are present; one of these, though incomplete at one end, measured 9,2 mm. long by 0,214 mm. wide; a fragment of another was 0,35 mm. in diameter.

There are also straight and curved spicules (figs. 8, 9) facsimiles of the larger spicules as regards their form but very much smaller. The straight forms of these small examples average 1,35 mm. long by 0,022 mm. wide, whilst the curved, shorter and proportionally stouter, average 0,585 mm. in length by 0,067 mm. in width. These curved spicules are abruptly pointed at both ends and very constant in form and size. Both the larger and smaller forms are abundant in the flint meal.

Simple acerate spicules are common to so many different forms of sponges that it is impossible to determine the relations of detached spicules with certainty, but, judging from the size of those in this deposit, they appear to me to correspond rather with accerates which in existing sponges are associated with the trifid spicules of Geodia and Stelletta than with the accerates of monactinellid sponges. Similar spicules are described by Mr. Carter from the Haldon Green Sand and referred to Geodia-like sponges (An. Mag. Nat. Hist. S. 4, Vol. 7, p. 129, Pl. 10, figs. 75, 76); they are present in the Upper Chalk of Coesfeld (Ueber Coelop. p. 36, Taf. IV, figs. 1—4) in the Chalk of the North of Ireland (Wright: op cit. Plate II, fig. 1) and also in the Eocene sand of Brussels (Rutot, op. cit. Pl. III, figs. 1—4).

Ophiraphidites, sp.

(Plate I, figs. 6—9).

Acerate spicules gradually tapering from the centre to either end; sinuous and curved in a great variety of forms. Some specimens have the main portion of the spicule nearly straight and the extremities abruptly bent in opposite directions, in other instances they are bow-shaped or curved in the form of the letter C. One of the largest specimens is 3,8 mm long by 0,13 mm wide; an average specimen measures 2,25 mm long by 0,09 mm. wide. They are very abundant.

These spicules correspond pretty closely with those which Mr. Carter discovered on the outer surface of some Atlantic sponges, to which he has provisionally given the name of *Ophiraphidites tortuosus*, it being at present doubtful whether they may belong to a distinct sponge or whether they are the acerates of a species of Pachastrella. (An. Mag. N. H. Dec. 1876 p. 458). Similar spicules are also present in the Haldon Green Sand, (An. Mag. N. H. Vol. 7 p. 131 Pl. X. fig. 79); in the Westphalian Chalk, (Ueb. Coelop. Taf. IV. fig. 24, 25) and in the Eocene sand at Brussels. (Rutot: op. cit. Pl. 3, figs. 5, 29).

Simple and Compound Trifid Spicules of Geodia and allied Genera.

Geodia? clavata n. sp.

(Plate I. fig. 4. plate II. figs 1—5.)

Very robust spicules with an elongate, straight or slightly curved shaft, constricted immediately beneath the head; below this, there is a bulbous inflation from which the shaft gradually tapers to a point. The head rays in all the simple forms, and in some of the compound as well, are but little more than short rounded knobs (fig. 1—35); in other compound heads the rays are more compressed and bifurcate into small pointed extensions. In some instances the number of the rays is limited to two. (fig. 1). The interior canal of the shaft is partially preserved; in some spicules it may be seen to extend throughout the entire length; in others only traces of it are exhibited in the inflated portion of the shaft, where it is expanded in the same manner as the shaft itself. Very rarely are canals exhibited in the head rays. In some spicules, which at first I thought might be acuate spicules with bulbous heads, but which I now regard as trifids in which the head rays have been broken off (Plate I, fig. 4), the canal is now extremely wide; but in the majority of the specimens the canal is partially or wholly infiltrated with silica. The surface of these spicules is very rough, and the peculiar radiate structure of the silica of the interior is well displayed. Scarcely any of these spicules are complete, the lower part of the shaft being mostly absent. A small specimen with the shaft complete has a length of 7 mm.; others in which the terminal portion is wanting, measure 8.77 mm. long, with a width of the bulbous portion of the shaft of 0,585 mm. They are not uncommon.

The gradual development of the rays of the head is well shown in different examples of these spicules. In one instance there are but two of these knob shaped rays, as if the summit of the shaft had been merely bifurcated (fig. 1); then follow specimens in which three simple knobs or rays are displayed (fig. 2), other specimens have one or more of these knobs but slightly constricted (fig. 3) whilst in others, the bifurcation of the rays is carried still further, the primary rays are somewhat compressed and flattened, and each extended into two short, obtusely pointed arms (fig. 4). The numerous transition forms would seem to indicate that these variously headed spicules may all have belonged to the same species of sponge.

I am unable to find any description of fossil or existing sponges with similar spicules; their form would indicate that they were probably the 'zone' spicules of a sponge like Geodia, and as they are distinct both in size and in the peculiar knob-like character ot the head rays, I propose to designate them Geodia? clavata. Spicules with a constricted neck, but with a somewhat different form of the head rays, and besides of much smaller dimensions are figured from the North of Ireland. (Wright: op. cit. pl. II fig. 14).

Geodia? coronata n. sp.

(Plate II fig. 6, 7, 8.)

Very robust spicules with a conical shaft, inflated at the upper end, and from thence gradually tapering to a point. Immediately on the inflated shoulder of the shaft, or with a very short intervening neck, are placed from 3 to 6 relatively very short, pointed rays, at a more or less open angle with the shaft. The shafts of these spicules are mostly straight, but in one example the lower end is curved. The rays, both of the simple and compound forms are very equal in size, and the compound rays bifurcate so close to the head of the shaft, that, in many instances, they appear to spring from it independently. As in the previous species, one or all of the primary rays of a spicule may become bifurcated. The total length of a small spicule (fig. 8) is 2,25 mm.; width across the head 0,45 mm.; diameter of shaft 0,27 mm. The length of an average spicule is 4,05 mm., the width of the rays 0,315 mm.; and of the shaft 0,45 mm. These spicules are somewhat rare.

From the peculiar arrangement of the rays, I propose to name this spicule Geodia? coronata. Similar spicules are present in the Chalk of the North of Ireland (Wright: op. cit. Pl. II fig. 13a, 13b).

Geodia? Wrightii n. sp.

(Plate II fig. 12).

Robust simple trifid spicules with an elongated shaft gradually tapering from the summit to the pointed extremity, the arms straight and directed forwards at angles varying between 35^0 and 60^0 with the shaft. The shaft furnished with from 10 to 14 ring-shaped expansions, extending at regular intervals from each other, from the summit to two-thirds or three-fourths of its length, the lower portion of the shaft being smooth. Each of the arms has also 4 to 6 similar rings. In some of the smaller spicules the rings of the shafts and arms are by no means so well defined as in the larger, and forms occur which show only traces of the rings, but I am unable to determine, whether this is owing to their non development or to subsequent erosion in these smaller specimens. The simple interior canal is shown in the larger forms. Length of an average large specimen 2 mm, width of shaft 0,247 mm.; width across the head 0,45 mm. Not very common.

I have named the spicule in honour of Mr. Joseph Wright F. G. S. who first discovered this form in the Irish Chalk (List of the Cretaceous Microzoa, Plate II fig. 5). In the figures of the Irish specimens, the rings extend quite to the extremity of the shaft, and in this respect differ slightly from the English forms. I have discovered similar spicules in material from Coesfeld and they are also present in beds belonging to the Lower Green Sand (Neocomian) in Surrey. *Quadrifid* spicules and also curved cylindrical spicules with similar ring-shaped expansions are described by Mr. Carter from the Haldon Green Sand under the names of *Monilites quadriradiatus* and *M. Haldonensis* respectively (An. Mag. N. H. S. 4 Vol. 7 p. 132 pl. IX, fig. 44—47) but the trifid form does not appear to occur in these beds. An annulated quadrifid spicule has also lately been discovered by Mr. Carter in an existing sponge, *Tisiphonia annulata* (An. Mag N. H. S. 5 Vol. 6 p. 494 pl. V. figs. 28 a. d.)

In addition to these trifid spicules, I have also found in the Horstead flint, a simple annulated acuate spicule similar in all respects to the trifid spicules but minus the capitate rays. At first I thought it might have been perfect for similar acuate forms are common in Chalk Flints in Oxfordshire, and also in the North of Ireland, but on examination under the microscope, I find that the head of the shaft is not evenly rounded off and that therefore the spicule is merely a headless trifid.

Stelletta? sp.

(Plate II fig. 9, 10.)

Robust spicule with straight gradually tapering shaft and simple trifid head; the rays stout, short and recurved. In one example the shaft has a contracted neck; in others, the shaft is thickest immediately beneath the rays. The incomplete spicule (fig. 9) has a length of 4,04 mm; width of head rays 0,63 mm; thickness of shaft 0,382 mm. The smaller but complete spicule (fig. 10) is 2,76 mm long; width of shaft 0,157 mm. The interior canals are partly preserved. These spicules are extremely rare.

Spicules similar in shape but much smaller are figured by O. Schmidt in *Stelletta Grubii* (Adriat. Spong. Taf. IV fig. 2 a, b) and Dr. Bowerbank represents the 'zone' spicule of *Stelletta* (Ecionemia) *coactura* (Mon. Brit. Spong. Vol. III p. 269 Pl. 82 fig. 16) with similar short curved head rays. This spicule occurs also in the Irish Chalk (Wright.: op. cit. Pl. II figs. 8. 9) and is referred by Bowerbank to Tethea and Geodia.

Stelletta? sp.

(Plate II figs. 11, 11a.)

Robust spicule with elongated gradually tapering shaft and head of simple conical, pointed, relatively very short rays, directed obliquely forwards. Length of specimen figured 3,98 mm., thickness of shaft 0,24 mm.; width across the rays 0,54 mm. Rare.

A spicule of similar form but only half the size is met with in *Stelletta Boylicii*, O. Schmidt (Sp. d. Adriat. Meeres p. 47 Taf. IV. fig. 4). The majority of the 'zone' spicules of Geodia, Stelletta, etc., have the head rays much more extended than is the case with this form of spicule. This form has also been met with in the North of Ireland (Wright: op. cit. Plate II fig. 9.)

Geodia? sp.

(Plate III. figs. 3, 6, 7, 9).

Moderately robust, simple and compound trifid spicules, with elongate, straight or slightly curved shaft. The head rays of the simple forms are short, conical, pointed and directed obliquely forwards; in the compound spicules the rays are stouter and more compressed, with the primary rays directed forward, but the secondary bifurcations extend in a horizontal direction. There are considerable differences in the dimensions of these spicules and the figures represent specimens of the average largest of each form. The smallest (fig. 9) has a length of 1.28 mm.; thickness of shaft 0,135 mm.; and width of head rays 0,405 mm. The larger, (fig. 3) has a length of 3,15 mm.; width of shaft, 0,22 mm. and width of head rays 0,742 mm. There are a number of examples of each of the four forms which I have figured and the examples of each form correspond pretty closely in size, so that it is quite possible that they may belong to more than one species of sponge. Spicules similar to these occur in other groups of sponges besides Geodia and genera allied to it. Thus a form similar to that placed under fig. 3 is found in *Ophiraphidites cretaceus*, Zittel (Stud. üb. foss. Spong. p. 98, Taf. XI, fig, 2 d) and it is also present in great numbers in the Lithistid sponge *Doryderma dichotoma*, Roemer, sp. (Stud. üb. foss. Sp. Taf. VII, fig. 1 c) but as none of the spicules of the mesh of *Doryderma* are found in the flint-meal, these trifids are not likely to have belonged to this species. Similar spicules are very abundant in the Haldon Green Sand and are included by Mr. Carter under the name of *Geodites haldonensis* (An. and Mag. Nat. Hist. Vol. VII, Pl. X, figs. 60, 61, 63, 66): they have also been figured by Zittel from the Upper Chalk of Coesfeld. (Ueber Coelop. Taf. VI, fig. 6, 9, Taf. VII, figs. 2, 3, 6).

Geodia? sp.

(Plate II, figs. 13, 14, 15).

Spicules with an elongated, moderately robust, straight, shaft, having a constriction at the upper end, below which, in some specimens, there is a slight inflation; the shaft gradually tapers to a point. The rays of the head are short, slightly curved at their junction with the shaft, then straight and pointed. They extend forwards nearly in a line with the shaft itself. Specimens with the rays bifurcate or compound are equally as numerous as those with the rays simple. These spicules are well characterized by the constriction at the top of the shaft and by the manner in which the head-rays extend directly forwards. The length of an average specimen is 2,29 mm.; thickness of shaft 0,135 mm.; and width across the head 0,2 mm. A spicule with a similar diposition of the head rays but apparently a larger form, is figured from the North of Ireland (Wright: op. cit. Pl. II, fig. 22).

This and a few other forms of spicule, described below, in which the head rays are either directed forwards or else recurved, appear to resemble those spicules of Mr. Carter's group of the Pachytragidae which he has termed «anchoring» spicules and it is probable that they were associated with the larger trifid spicules, which I regard as the «zone» spicules of the same division of sponges. As a rule these fossil «fork» and «anchor» spicules are much larger than those in existing sponges, bùt this might be expected from the greater dimensions of the «zone» spicules.

Geodia, sp.

(Plate II, figs. 17, 18, 19).

Somewhat delicate spicules with an elongate gradually tapering shaft, and simple, straight or curved, pointed rays extending forwards from the shaft. The rays are frequently unequal in length und occasionally one is aborted and the spicule is bifid. I have not noticed any specimens of this form with compound or bifurcate rays. There is considerable variation in the size of these spicules; a large specimen (fig. 17) measured 3,15 mm. long by 0,09 mm. wide. A smaller form (fig. 19) is 1,01 mm. long and the thickness of the shaft is 0,045 mm.

A spicule closely resembling fig. 17 is figured by Dr. Bowerbank from *Geodia Zetlandica* (Mon. Brit. spong. Vol. III, p. 15, Pl. VII, fig. 8).

Geodia? sp.

(Plate II, fig. 16).

Spicule with a delicate, straight, gradually tapering shaft and three slender simple rays, unequal in length and recurved, each of the rays being of nearly the same thickness as the shaft, Length (incomplete) 1,05 mm.; width 0,067 mm. Very rare. This spicule is of the same character as the preceding, but the arms are recurved, anchor-like.

Tethya? sp.

(Plate III, figs. 1, 2, 13, 14).

Simple trifid spicules with a relatively very variable length of shaft, which is straight or curved, gradually tapering and in most instances obtusely pointed; the arms of the head rays are very long, frequently of unequal length in the same spicule; stout, conical, curved, pointed and directed forwards at a very open angle with the shaft. There is a very great amount of variation in the length and in the relative proportion of the arms of these spicules; in some examples, one of the rays becomes nearly as long as the shaft. In no instance do the arms bifurcate. The length of one of the largest specimens (fig. 2) is 4,025 mm.; width of shaft 0,247 mm,; width of head rays 1,35 mm. In another form (fig. 13), in which the shaft is constantly straight and but little stouter than the arms, the total length of the spicule is 1,8 mm. diameter of the shaft 0,18 mm.; and the width across the head rays 1,37 mm. The length and spreading disposition of the rays give these spicules an altogether different appearance to those which I have already referred to Geodia. They are not uncommon in the flint-meal.

The only fossil spicules, which, to my knowledge, at all resemble these specimens, are those of *Tethyopsis Steinmanni,* Zittel (Stud. über foss. Spong. p. 99, Taf. XI, fig, 3) from the Upper Chalk at Ahlten in Hanover.

Tethya? sp.

(Plate III, fig. 10).

Simple trifid spicules with elongated gradually tapering shaft and three *equal,* short, conical, slightly curved and pointed rays, projecting forwards at a wide angle with the shaft. Average length of large spicule 2,47 mm.; diameter of shaft 0,135 mm.; width across the head rays 0,83 mm. Not uncommon.

Tethya? sp.

(Plate III, fig. 4).

Simple trifid spicule, shaft straight, stout, rapidly tapering; head rays short, cylindrical and nearly at right angles to the shaft. Length of spicule 2,29 mm.; diameter of shaft, 0,315 mm. extension of head rays 0,8 mm. This peculiar shaped, robust spicule occurs but rarely. It has been found in the Chalk of the North of Ireland (Wright: op. cit. p. 89 Pl. II, fig. 12) and Dr. Bowerbank states that a similar form is present abnormally in some species of Tethya, but at present I have failed to find any representation of a similar spicule.

Tethya? sp.

(Plate III, fig. 5).

Robust simple trifid spicule with stout, straight, tapering shaft and conical, straight, moderately long, obtusely pointed arms, which are extended nearly at right angles to the shaft. Length 2,07 mm.; thickness of shaft 0,2 mm. and extension of the head rays 1,08 mm. Very rare.

Tethya? sp.

(Plate III, fig. 8).

Simple robust trifid spicule, with a very stout, short, rapidly tapering shaft, on the summit of which are three short cylindrical rays, directed forwards at an acute angle with the shaft. Length of shaft 1,95 mm.; thickness 0,27 mm.; extension of head rays 0,517 mm. This spicule is distinguished from the preceding by the arms being longer, not so stout and also directed forwards. Rather rare.

These three last described spicules (Plate III, figs. 4, 5, 8) resemble each other in having comparatively short and robust shafts and cylindrical, stout, simple, head rays, at the same time each form is distinctly marked off from the others by differences in the shaft and disposition of the head rays, so that they may have belonged to as many species of sponge. This form of spicule differs considerably from the «zone» spicules of existing sponges of the genera Geodia, Stelletta and Tethya, nevertheless their affinities appear to approach nearer to the spicules of this, than of any other group of sponges.

Siliceous Globules and Globo-stellates of Geodia and allied Genera.

(Plate I, figs. 25, 26. 27).

There are present in the contents of this Horstead flint, three different forms of the small siliceous bodies which are so abundant in the dermal crust of the recent sponges belonging to Geodia and its allied genera. The first of these (fig. 25) are small bodies, either nearly spherical or ellipsoidal in form, and showing, in many examples, an irregularly shaped cavity in the interior. The surface is now rough but appears to have been originally smooth. An average specimen of the ellipsoids, which is the prevailing form, measures 0,292 mm. and 0,247 mm. in the longer and shorter diameters respectively. I have not noticed any trace of depression or hilum in any of these bodies, which are abundant.

There can scarcely be any doubt that these small ellipsoids belong to the dermal crust of a sponge similar to Geodia. The beautiful radiate arrangement of the «siliceous balls» of the recent sponges has however, through the alteration of the silica, quite disappeared in these examples, but I have had the opportunity of comparing them with similarly shaped spicules from the Upper Chalk of Coesfeld in which the radiate structure is still preserved equally as perfect as in those of existing sponges. In the Coesfeld examples I have noticed a small cavity in the central portion of the spicule, into which the radiate structure does not extend, and to the enlargement of this originally small cavity may be attributed the irregularly shaped interior hollows of the Horstead specimens. This is further confirmed by finding in one of the Coesfeld examples, an abnormally enlarged central portion, while the exterior portion of the spicule yet retains the radiate structure.

Excellent illustrations of the radiate structure of these bodies in the existing sponge *Geodia Mc'Andrewii*, Bowerbank are given by Dr. Bowerbank (Mon. Brit. Spong. Vol. I, Pl. XXIII, XXIV, figs. 326—335. Similar siliceous globules are described by Mr. Carter from the Haldon Green Sand (An. Mag. Nat. Hist. Vol. VII, Pl. IX, figs. 55. 56); by Prof. Zittel from Coesfeld (Ueber Coelop. Taf. V, figs. 18—20); and also by Rutot from the Eocene Sand of Brussels (op. cit. Pl. III, figs. 36, 37).

The second form of these siliceous bodies (fig. 26), which Mr. Carter has termed globo-stellate consists of a minute spherical body whose surface is thickly studded with very minute pointed spines. They average 0,18 mm. in diameter. In existing sponges a somewhat similar form of globo-stellate is present in *Stelletta lactea*, Carter. (An. Mag. Nat. Hist. S. 4, Vol. VII, p. 9, Pl. IV, fig. 21 a) and also in *Tethya robusta,* Bowerbank. (Mon. Brit. Spong. Vol. I, Pl. VI, fig. 165) and it is probable that these Horstead examples be long to one or other of these genera. O. Schmidt has also noticed the similarity of the globo-stellates of Tethya and Stelletta. (Spong. d. Küste von Algier. p. 21). Globo-stellates precisely similar to those from Horstead are also present at Coesfeld. (Ueber Coelop. Taf. IV. figs. 28, 30).

In the remaining form of globo-stellate (fig. 27) the spicule is larger and the rays are proportionately longer and not so thickly set on the surface as in the form just described. In an average specimen, the diameter, including the rays, is 0,29 mm. and the rays have a length of 0,0675 mm. Varied forms of these globo-stellates appear to be present in the same specimen of sponge and these spicules probably belong to the same species as the preceding. A similar body is figured by Rutot from the Eocene of Brussels, (op. cit. Pl. III, fig. 35).

Free Siliceous Discs of Stelletta?

(Plate I, figs. 23, 24, 28).

Besides the minute globates and globo-stellates, there are present in the Horstead flint, two forms of small, flattened disc-like spicules. One of these (fig. 23) is an extremely delicate, thin disc, circular in outline, with a well defined smooth border and an apparently smooth outer surface. Arranged at regular distances round the border of the disc is a series of about 18 extremely delicate flask-shaped canals, having their narrow end directed to the edge of the disc, which, however, they do not reach, and extending somewhat more than one third of the distance to the centre. Between each of these canals, there are two, and occasionally three, still smaller oval canals arranged at the same distance from the edge of the disc. There is no trace of any canals radiating from the centre. These discs are tolerably uniform in size and have an average diameter of 0,315 mm.

The other form of disc (fig. 24) is likewise extremely thin; elliptical in form, and having the outer edge deeply notched or scalloped at regular intervals. In most of the specimens the canals are obliterated, but one fragmentary disc (fig. 26) shows about 18 straight canals radiating from the centre towards the circumference. The long diameter of these specimens measures 0,27 mm., and the shorter 0,18 mm. Both forms are rare.

Professor Zittel has described and figured similar discs from the Upper Chalk of Westphalia, (Ueber Coelop. p. 47. Taf. V. figs. 32—35) and he is disposed to regard the discs with the scalloped edges as the incomplete forms of those with the even border. The Westphalian specimens lend greater probability to this supposition than the Horstead examples, for some of the even bordered discs from Westphalia have, in addition to the flat and oval shaped canals near the border of the disc, a variable number of canals radiating from the centre to the circumference similar to those in the scalloped discs. In the Horstead specimens, on the other hand, the canals radiating from the centre only appear in discs of this latter form, and as these are all elliptical in outline as well, in contrast to the circular even bordered discs, I think that these two forms of discs may be considered as separate from, though closely allied to each other.

Similar discs with numerous radiating canals have not yet been discovered in existing sponges, so that there is no direct clue to the affinities of these small bodies. Mr. Carter discovered two of the even bordered discs in the Haldon Green Sand and regarding them as allied to the circular and branched discs which form the surface spicules of Discodermia and other allied Lithistid sponges, named them

Dactylocalycites callodiscus (An. Mag. N. H. S. 4 Vol. 7 p. 123 Pl. IX. fig. 40). It seems to me however, that the affinities of these discs is rather with the siliceous globules and stellates of Geodia and other genera of Tetractinellid sponges than with the Lithistidae. In the surface spicules of both recent and fossil Lithistids, in which canals are present, they are restricted to three, which afterwards bifurcate in some instances. In no known instance of ascertained Lithistid surface spicule is there the number and disposition of the canals as in these isolated discs. Considerable light is thrown upon the affinities of these discs from the description which O. Schmidt has given of the different stages of growth of certain thin oval discs present in the existing sponge *Stelletta Euastrum* (Spong. d. K. von Algier, p. 20, Taf. IV, fig. 4). In the earliest stage of the development of these discs there is a granular centre from which a single layer of extremely delicate needle-like rays or spicules radiate. More developed specimens show these fine ray-like spicules united near their bases and deeply notched at the periphery. In the complete disc one surface is smooth, flat, or slightly concave, whilst the other is convex and thickly covered with small warts.

The structure of these discs from the Upper Chalk may be understood, if we suppose that in a similar manner to those of *Stelletta Euastrum*, they have been developed by the amalgamation of a single layer of very fine spicules radiating from a centre and that the shorter and longer canals which are shown in the discs are those of the spicular rays of which they are composed. Although O. Schmidt does not mention the presence of canals in the spicular rays of the discs of *Stelletta Euastrum*, he yet states that he has repeatedly noticed a central canal in the similar and equally minute spicular rays of the siliceous globules of *Geodia canaliculata* (Spong. d. K. von Algier, p. 21). There appears therefore a probability that these small bodies are the surface discs of a species of Stelletta.

Tisiphonia? sp.

(Plate III, figs. 16—23).

Compound trifid spicules, with stout, straight, more or less developed shaft and very robust head rays, which are bifurcated and widely extended in a horizontal direction. As will be seen by the figures, there is great variation in the relative dimensions of the arms and the shaft in these spicules. In some specimens (fig. 17) the shaft is comparatively long and the head rays stout, and but moderately expanded. The example figured has a length of 2,115 mm., the shaft is 0,112 mm. in diameter, and the extension across the head 1,26 mm. Another spicule (fig. 18) has a shorter and thicker shaft and also stouter head rays. Figs. 16 and 20 show forms in which the head rays are slender aud more divergent. In fig. 21 the shaft is truncated and rounded at the end. In fig. 22 the shaft resembles a stout cone and the head rays are also very robust and obtusely pointed. This specimen has a length of 1,35 mm.; thickness of shaft 0,247 mm. and the extension of the head 0,967 mm. Lastly in figs. 19 and 20 we have examples in which the head is largely developed and the shaft of the spicule has become reduced to little more than a mere rounded prominence. The width of the head in these specimens is 1,6 mm. The figures show also, how unequally the head rays of these spicules are developed; in some examples the primary rays are symmetrical, comparatively long and extend some distance from the centre before they bifurcate and then give off long pointed secondary rays (figs. 16, 20); in other specimens the primary rays are so wide that they amalgamate and form a solid laminated centre from which the unequally developed, obtusely blunted secondary rays are given off. In many specimens the canal system is very distinctly shown, those of the arms radiating from the centre of the shaft and sending a branch to the extremity of each ray.

Such differences of size and form indicate that these spicules may have belonged to several species of sponge and this is rendered further probable by the great numbers which are present in this Horstead flint.

I have some difficulty in determining the relationship of this group of spicules with existing forms. The compound trifid spicule with the head expanded horizontally frequently forms the «zone» spicule of Geodia and Stelletta, but accompanied by an elongated shaft; a similar form of spicule is present in the dermal portion of many species of Lithistids, but these are so diminutive in comparison with those figured as to negative the probability of their being surface spicules of these sponges; I also compared them with the truncated spicules of Pachastrella, but these have the arms mostly simple, or where bifurcated, the division is generally restricted to the ends of the arms; at last I found the description of a sponge with a similar spicule, placed by Mr. Carter under the name of *Tisiphonia nana* (An. Mag. Nat. Hist. S. 5, Vol. 6, p. 492, Pl. VII, fig. 43 a, b). This spicule has a truncated shaft and an expanded head closely resembling some of the Horstead forms. Further, O. Schmidt has figured the head of a spicule similar to that of fig. 20 in a sponge from the Adriatic under the name of *Stelletta Hilleri* (Supp. d. Spong. Adriat. Meeres, p. 32, Taf. III, fig. 8) and as according to Mr. Carter the genus Stelletta is equivalent to Tisiphonia, there is a probability that these spicules with truncated shafts may be the «zone» spicules of sponges allied to Stelletta, notwithstanding the great differences which they present, in the comparative reduction of the shaft and the extended development of the head, from the typical «zone» spicules of Stelletta itself.

Similar spicules but as a rule very much smaller in dimensions, have been found by Mr. Carter in the Haldon Green Sand (An. Mag. Nat. Hist., S. 4, Vol. 7, Pl. IX, figs. 30—36); they are also present in the Chalk of the North of Ireland (Wright op. cit. Pl. II, figs. 17 a, b) and

Westphalia, (Zittel: über Coelop. Taf. VI, figs. 16—29) and in the Eocene sand of Brussels (Rutot: op. cit. Pl. III, fig. 9).

Quadrifid Spicules of Pachastrella.

Pachastrella, sp.

(Plate III, figs. 24, 25).

Simple quadrifid spicules in which three elongated arms radiate at equal angles from a centre and form the outline of a more or less elevated three-sided pyramid, from the apex of which another arm generally shorter than the other three, extends upwards. There are two very distinct forms of these simple quadrifid spicules. In the larger (fig. 24) the three arms form a very low pyramid; in some examples they are nearly in the same plane; and the fourth arm, much shorter than the other three, is nearly at right angles to them. The other three arms are nearly equal, straight and pointed, and in no instance which I have noticed are they bifurcated at the extremities. Canals are shown in some examples, much wider than those in similar spicules of recent sponges. These spicules are abundant and very uniform in size. The average length of the *arm* of a fair sized spicule is 1,035 mm. and its thickness near the centre is 0,09 mm. The vertical arm has a length of 0,2 mm.

In the smaller form of quadrifid spicule (fig. 25) the four arms are nearly equal in length and they are disposed so as to form a more elevated pyramid. The average length of each arm is 0,45 mm. and the thickness near the centre 0,045 mm. These spicules are also very abundant.

From comparisons which I have made with specimens of *Pachastrella amygdaloides*. Carter, and *P. geodioides*. Carter (An. Mag. Nat. Hist., S. 4, Vol. 18, p. 406, Pl. XIV, figs. 22, 23) from the Atlantic, I find that there is a striking resemblance in the spicules of the recent sponges and those from the Horstead flint. Beyond the differences in the state of preservation there is scarcely anything to distinguish the fossil Chalk spicules from those of the existing sponge, *P. amygdaloides* which was dredged from a depth of 292 fathoms near Cape St. Vincent.

Similar spicules, as regards form, have been found in the Irish Chalk (Wright: op. cit. Pl. II, fig. 7 a, b) in Westphalia (Ueber Coelop. Taf. V, figs. 54, 55) and also in the Eocene Sand of Brussels (Rutot: op. cit. Pl. III, fig. 8).

Pachastrella Carteri, n. sp.

(Plate III, figs. 29, 30, 31).

Simple quadrifid spicules, with short robust, cylindrical or conical, and obtusely rounded arms, forming a depressed pyramid with a short arm at the apex. In figs. 29 and 31, the stout conical blunted arms vary from 0,47 mm. to 0,67 mm. in length, and are 0,225 mm. in thickness. In the more regular spicule (fig. 30) the arms are cylindrical and measure 0,337 mm. by 0,112 mm. These spicules appear intermediate between those forms of skeleton spicule with long pointed simple arms of which *P. amygdaloides,* Carter is the type, and those in which one or more of the arms are bifurcated at the extremities as in the recent sponge *P. abyssi,* O. Schmidt, and the fossil, *P. primoeva,* Zittel. It is true that in both the recent and fossil Pachastrellid sponges, various forms and sizes of quadrifid spicules are present in the same sponge, but as I have not noticed any sponges with spicules having the short, blunted arms of these examples, I think they may belong to a distinet species, which I propose to name in honour of Mr. H. J. Carter F. R. S.

Pachastrella primaeva?

Zittel: Stud. über Foss. Spongien p. 100, Taf. XII, fig. 4.

(Plate III, figs. 28, 32, 33, 34).

Spicules with four unequal arms, straight or slightly curved, of which three are disposed nearly in a plane or forming a very depressed pyramid. One arm of these three is frequently longer than the others, slightly curved, and at the extremity bifurcates into two small irregular rays (fig. 32, 33). The arm at the apex of the pyramid is short and obtusely blunted and in some instances is continued beyond the apex of the pyramid, so that a five-armed spicule is the result, (figs. 28, 34), As in other respects these five-armed spicules correspond closely with the four-armed, I am disposed to consider them as mere variations and not as indicating a different species. The length of the arms of these spicules varies between 0,495 mm. and 1,125 mm. with an average thickness of 0,14 mm. The examples of these quadrifid spicules are but rarely met with.

These spicules correspond so closely with those of *Pachastrella primoeva*, Zittel, from the Upper Chalk of Ahlten in Hanover, that, so far as can be judged from the zone spicules, they may have belonged to the same species. In the Ahlten sponge, the larger spicules are also accompanied by great numbers of the smaller simple quadrifid spicules similar to those of my fig. 25, and these smaller forms both in the fossil and recent sponges seem common to different species of Pachastrella. I have also seen a specimen of Pachastrella from the Flamboro' Chalk, given by Mr. Carter to Professor Zittel, in which the furcation of the skeleton spicule is carried to a greater extent than in the Ahlten and Horstead examples, and the spicule is also less robust. In the furcation of the extremities of the spicule, the Chalk examples correspond closely with the skeleton spicules of *Pachastrella abyssi*, O. Schmidt, and also with *P. intertexta*, Carter. (An. Mag. Nat. H. S. 4. Vol. 18. p. 409 Pl. XV. fig. 41) dredged from the Atlantic near Cape St. Vincent at a depth of 374 fathoms. Examples of the five-armed spicules also occur in *P. intertexta* and in *P. parasitica*, Carter (An. Mag. Nat. Hist. S. 4. Vol. 18. p. 410 Pl. XVI, fig. 50.)

Pachastrella? sp.

(Plate III, fig. 27.)

Spicules with three straight slender arms radiating at equal angles and in one plane. The extremities of the arms are not preserved, but they are nearly uniform in thickness throughout, and frequently one is shorter than the other two, but whether this is merely accidental I am unable to say. Average length of arms 0,61 mm. and width 0,045 mm. Not uncommon.

It is doubtful whether these three-armed spicules are merely spicules in which a fourth arm has not been developed or whether they belong to a different group of sponges than the Pachastrellidae. Mr. Carter states that in *P. amygdaloides* large triradiates are present in which the fourth arm or shaft is only represented by a short extension of the central canal *inside* the spicule; and *P. connectens*, O. Schmidt (Atlant. Spong. p. 65) is also stated to have large three-rayed spicules; and similar forms are also represented in *Sphinctrella horrida*, O. Schmidt (op. cit. p. 65) so that it is not improbable that they may belong to a species or Pachastrella.

Caminus? sp.

(Plate III, fig. 26.)

Spicule with three unequal arms in the same plane. One arm is stout, short, and rounded at the extremity, the others are elongated and gradually tapering. Length of shorter arm 0,38 mm.; thickness 0.067 mm. I have only met with a single specimen. The only instance which I have seen of a spicule of corresponding form is represented in *Caminus apiarium*, O. Schmidt, (Atlant. Spong. p. 71. Taf. VI. fig. 14) from the coast of Florida. The scale to which O. Schmidt's figure is drawn is not stated, so that I am unable to make a comparison as to their relative dimensions.

Order Lithistida, Oscar Schmidt.

In this order are comprised sponges whose skeleton is built up of spicules which are united together by the interlocking of the extremities of their arms to form a more or less open mesh or net work. In addition to the spicules composing the mesh-work of the body of the sponge, there are, in most, if not all the Lithistids, other spicules, frequently of quite a different form to those of the mesh, which are arranged on the outer surface of the sponge and may be termed surface spicules in contradistinction to the mesh or body spicules. In existing sponges of this order minute 'flesh' spicules are also present, but these have not been preserved in the fossil examples.

The intimate manner in which the spicules of the mesh are interwoven together by the curiously modified extremities of their arms, has enabled the sponges of this order to retain in many instances their form complete in a fossil condition. As remarked by Zittel (Studien p. 79) the spicules do not usually fall asunder and become detached after the death of the animal, and Mr. Carter has also recently stated that the mesh spicules of existing Lithistids are, for the most part, so locked together that even boiling in nitric acid does not cause them to detach and fall asunder. (An. Mag. N. Hist. S. 5, Vol. 6 p. 496). It is to this fact that the larger portion of known fossil sponges belong to this order, though, if one may judge from the proportion of the detached spicules of Tetractinellid sponges in this Horstead flint, as well as at Haldon and in Westphalia, the Tetractinellids may have been equally as numerous in the same strata with the Lithistids, but that owing to their skeleton being built up of disconnected spicules, and the inevitable dispersion of these in nearly all cases after the death of the animal, their remains have, up to the present, been but little noticed. At the same time that the skeleton of fossil Lithistid sponges has been very often preserved entire, there seems reason to believe that in the majority of instances the skeleton of the sponges of this order after the death of the animal, fell apart and became resolved into its constituent spicules. Such at all events appears to have been the case in the Horstead Chalk. In this Chalk, so far as I am aware, not a single *entire* Lithistid sponge has been discovered, and yet in the contents of this single flint from the same locality there are inclosed such a number and variety of detached Lithistid spicules as to make it evident, that the order was represented by numerous species. Nor has this disintegration of the Lithistid sponges in the Chalk been brought about by mechanical influences, for the individual spicules are entire and present only those alterations in their structures which are common to all the spicules of this flint meal. Notwithstanding the great abundance of single spicules, there are but few specimens in which two or more of these spicules yet remain together in their natural connection.

In this order there is an extraordinary variety of form in the individual spicules of the skeletal mesh-work, as also in the manner in which they are combined together. In some spicules, the plan of growth is similar to that of the four-armed spicules of Pachastrella, in others, the form is so irregular that no definite system of growth can be perceived. While, to some extent, the difficulties attending the determination of the affinities of the detached spicules of the Tetractinellid sponges are also present in the case of the Lithistids, yet the very peculiar form of the Lithistid spicules and the varied methods by which they are attached to each other to form the mesh of the skeleton, furnish reliable indications of their relationships; besides which the investigations of Zittel, Carter, O. Schmidt and Sollas have supplied the means of comparison with a number of genera and species, and thus in many instances enabled the systematic position of the detached spicules to be satisfactorily ascertained. In some instances several different genera have the mesh spicule so nearly alike that it is impossible to determine to which of the group the detached spicules may belong, in other cases the spicules belonging to a single genus are very clearly differentiated. Professor Zittel has divided the order of Lithistidae into four Families according to the structure of the spicules of the mesh and two of these families are present in the Horstead flint.

Family Megamorina, Zittel.

The Skeleton spicules of this group are comparatively large, elongated, oftentimes branched bodies, mostly very irregular in their form. They are united together to form the skeletal mesh either by having the concave expansions of the terminal arms of the spicules, closely fitted against the arms of adjoining spicules as in the Genus *Lyidium*, O. Schmidt; or by the intertwining of the extremities of the spicules round each other as in the case of the genera *Carterella*, Zittel and *Isoraphinia*, Zittel.

Genus Lyidium, O. Schmidt 1870.
Lyidium Zitteli n. sp.

(Plate IV, figs. 1—9).

Robust elongated spicules, simple or branched, of various forms, with the extremities of the arms transversely expanded and concave, so as to be attached to the surfaces of adjoining spicules. Average diameter of the arms of the spicules 0,112 mm.

There is such an extraordinary diversity in the forms of the spicules of this species, that in some hundreds of examples which I have seen, I do not think two similar ones could be found. The simplest form is a curved spicule with the two ends transversely expanded (fig. 2); from this, the next stage is a curved spicule with a projecting arm in the centre of the curve (fig. 4), then one or both ends of the simple spicule are bifurcated; another spicule has three arms radiating from a common centre as shown in the central spicule of fig. 3; other spicules have a straight or curved main stem from which one to four branches are given off at various angles and in different directions, each branch, as well as the stem itself having expanded terminations (figs. 5, 7, 9), in other spicules one end of the main stem is not expanded but terminates in an obtuse point (figs. 6, 8); in short, there is an endless multiplicity of form of which only the more striking varieties are indicated in the figures. At the terminations of the stems and branches of these spicules, there is a more or less elongated expansion at right angles to the direction of the branch, and this is hollowed out lengthways in such a manner that the depression exactly fits the convex surface of the arms of other spicules and tightly grasps them so as to form a strong complicated network with irregular openings. A few specimens occur yet showing the manner in which the spicules of the mesh were united together (figs. 1, 3) but these examples are very rare in comparison with the number of isolated spicules. Nowithstanding the great variety of form, the spicules are very uniform in thickness, and one may compare the skeleton to a piece of complicated wire netting made up of innumerable fragments, cut and twisted into different forms but all from the same strand of wire and fastened together in a similar manner. The surface of the spicules appears to have been originally smooth, though now rough and pitted, and the delicate edges of the expanded extremities have in most instances lost their evenness of outline. It is perhaps owing to the erosion of these extremities that the spicules lost their hold and became detached from each other. In one solitary instance only have I noticed a canal in the interior of a spicule.

The type, and up to the present, the only described species of the Genus *Lyidium* is a fragment of sponge dredged up from the Atlantic, off the Coast of Cuba, at a depth of 270 fathoms, on which O. Schmidt, on account of the highly characteristic form and arrangement of the spicules, constituted the genus. I have had the opportunity of examining a fragment and also mounted slides of the original specimen, which were presented by O. Schmidt to Prof. Zittel, and have thus been able to compare the fossil Chalk spicules with those of the existing sponge. The spicules of the existing sponge have the same diversity of form and are attached together by the close fitting expanded extremities in a similar manner to the Horstead flint spicules, but the mesh is of a more open character and the thickness of the spicules is considerably less, in a word, to continue the simile, the strand of wire is, in this case, of a different thickness having an average diameter of 0,045 mm. but little more than one-third the thickness of Lyidium Zitteli. It is on this difference of thickness of the spicules and on the closer character of the openings of the mesh that I venture to constitute these fragments and spicules into a distinct species, which it gives me great pleasure to name in honour of Professor Dr. Karl Zittel.

Though first noticed as an existent sponge, the genus Lyidium appears to have had a wide distribution in the past. Mr. Carter has figured a number of spicules from the Haldon Green Sand whose similarity of form to *Lyidium torquilla* O. Schmidt, he has noticed (An. Mag. Nat. Hist. S. 4, Vol. 7, p. 118, Pl. VIII). Judging from the figures, these green sand spicules are of a greater thickness than those from Horstead. Spicules resembling those of Lyidium are figured by Mr. Wright from the North of Ireland (op. cit. Pl. III, figs. 2 a, b, 3 a, b) and are referred to by Dr. Bowerbank as «singular and probably abnormal form of dermal spiculum of a siliceo-fibrous sponge» I have also seen Lyidium spicules from the Chalk of Oxfordshire which were discovered by the Rev[d] R. Pattrick of Warbro' Lastly, they are figured by Zittel from the Chalk Formation of Westphalia (Ueber Coelop. Taf. VII, fig. 38

and I have myself obtained them in great abundance in material from Coesfeld.

Lyidium cretacea, n. sp.

(Plate IV, figs. 10—13).

Moderately robust spicules of very various forms, the branches sometimes expanded at their extremities but frequently elongated and obtusely pointed. The mesh work of the skeleton of a more open character than in the preceding species. Average thickness of the spicules 0,09 mm.

The spicules of this species can be readily distinguished from those of *L. Zitteli*, by their lesser thickness, the greater frequency in which the spicular arms terminate obtusely and by the openings of the net work being proportionately larger Not very abundant.

Genus Carterella, *Zittel* 1878.

Carterella, sp.

(Plate IV, figs. 14—23).

Robust, straight or curved, elongated spicules, smooth, cylindrical or compressed, having at their extremities a small, thin, tongue-like prolongation frequently bent into a hook-like form. Occasionally the end of the spicule is blunted and forms a slight knob. The spicule is also, near the extremities, and sometimes in the centre, transversely grooved or deeply notched. As a rule, however the central portion of the spicule is smooth and rounded. Average length of spicule 1,5 mm.; average thickness 0,085 mm. Not infrequent.

The sponges of this genus are long cylindrical bodies, composed of spicules, resembling those figured. These spicules are intertwined round each other, principally at their notched extremities, like the strands of a rope; the notches in the spicules permitting a very close union of the ends of the spicules with each other, while the central portions of the spicules are only laterally pressed together. Though I have not obtained specimens in which the spicules are attached together yet the isolated spicules so closely correspond in general form with the type of the genus, *C. spiculigera,* Roemer, sp. from the Upper Chalk of Hanover that there can hardly rest a doubt of their belonging to it. The spicules of *C. spiculigera* are however both longer and thicker than those in the Horstead flint, and it is therefore probable that the latter belong to another species. In the Hanover spicules, a central canal extends along the axis of the spicule but this has been obliterated in the Horstead examples.

Family Tetracladina, *Zittel.*

In this group of the Lithistidae the individual spicules are mostly built upon a quadriaxial type and consist of four arms radiating from a common centre. The extremities of the arms are split up into small branches and twigs, and it is by the complicated interweaving of these minutely divided extremities that the spicules unite with each other to form the skeletal mesh work. Besides these four-rayed spicules of the mesh, probably all the sponges of this division are furnished with a surface layer ot spicules, mostly of a very different shape to those of the mesh. In some instances these surface spicules are delicate laminae of various forms, as in the Genus Plinthosella; in others they are trifid spicules, in which the shaft has been reduced to a mere point and the head rays have coalesced to form discoidal heads with irregular borders, as in Racodiscula; whilst other surface spicules resemble in form the compound trifid spicules of Geodia, and are only distinguished from the zone spicules of that genus by their much smaller size. As a rule the individual spicules of many of the sponges of this family are very minute, and their slender arms and delicate branched extremities have been considerably eroded by the process of fossilization.

Genus Plinthosella, *Zittel* 1878.

Plinthosella squamosa, *Zittel*.

(Studien über fossile Spongien p. 153, Taf. 10, fig. 5).

(Plate IV, figs. 35—46.)

Spicules of the mesh robust, mostly four armed, but the arms unequal, straight or curved and radiating from the centre at different angles. The surface of the entire spicule is completely covered with prominent rounded wart-like projections. The extremities of the spicular arms are frequently split up into small twigs, which are twined round the arms of adjoining spicules, and the spicular arms themselves are closely adpressed together so that the warty projections interlock with each other; by this means a very compact skeletal mesh work is formed. Length of arm of large spicule 0,75 mm.; average thickness 0,16 mm. The surface spicules of the sponge are formed by delicate laminated plates of varying forms, either circular, (fig. 45); oval (fig. 46); straight and narrow, (fig. 43) or curved and tapering to both ends. The narrow plates are about 2 mm. in length and 0,157 mm. in width, whilst the circular plates have a diameter of 1 mm.

The mesh spicules of this sponge are mainly characterized by their robust proportions, the inequality of their arms, and the prominent rounded knobs with which these are furnished. In some instances, the spicules are apparently formed but of three rays or arms, two of which are often in the same plane and at right angles to each other, other spicules have bent and curved arms, some as long again as others. Most of the arms terminate in two or three minute, irregular, twig-like extensions which serve to attach the spicules to each other to form the mesh. These twig-like extremities do occasionally intertwine with the similar terminations of adjoining spicules, but, as a rule, they grasp round the sides of the spicular arms, and oftentimes the arms of different spicules are, for their entire length, in close connection with each other, so that the rounded projections on their surfaces are, as it were morticed together. The not infrequent specimens in which the spicules yet remain attached together, prove that the skeletal mesh was better able to resist disintegrating influences than most of these Chalk Lithistids. The surface or dermal spicules of this sponge strikingly differ from those of most other Lithistids. They consist of extremely thin delicate plates or laminae, of regular and irregular forms, which appear to have formed a covering over the exterior of the sponge, their edges overlapping each other. There is no trace of any shaft as in the surface discs of Discodermia, and these spicules must have been held in place by the living sarcode. Neither is there any indication of interior canals; so that, in this instance at least, the surface spicules cannot be regarded as modifications of the skeletal mesh spicules. Some of these dermal spicules have the form of straight laminae, widest in the centre and gradually tapering to either end. Others of about the same width are curved, and the lower portion bent round in such a manner that the spicule has a tendency to stand on edge, as shown in fig. 44. Other spicules are circular or oval in outline whilst some few are irregular in form. Of each regular form of these laminated spicules there are numerous examples in the Horstead flint, those of each form agreeing also in size with each other. The relations of these differently shaped laminae to each other was apparent at the time of my picking them out of the deposit, but had they not been discovered in their natural position on the surface of the sponge with the well-marked mesh spicules, I think it would have been inpossible to have recognized in them the dermal spicules of a Lithistid sponge.

The sponges to which these mesh spicules and laminated dermal spicules belong, *Plinthosella squamosa* Zittel, are small spherical bodies from 5 mm. to 25 mm. in diameter. The spicules form a coarse irregular mesh work, traversed by canals which also form irregular furrows on the surface of the skeleton, beneath the dermal layer. By the careful removal of the matrix, the dermal laminae can be seen in places on the surface of the sponge which they appear to have completely covered and the differently-shaped laminae are present in the same individual sponge. A comparison with the type specimens show such a close agreement both of the mesh and dermal spicules that there can hardly be a doubt, but that these Horstead spicules belong to the same species. *P. squamosa* is from the Upper Chalk of Ahlten in Hanover.

Genus Ragadinia, *Zittel* 1878.

Ragadinia annulata n. sp.

(Plate IV, figs. 24—30. Plate V. figs. 1—4.)

Spicules of the mesh (Pl. V, figs. 1—4) minute, irregularly four-armed; frequently one arm truncated and having a round knob at its termination; the other arms having a single prominent ring-shaped expansion a short distance from the centre, but otherwise with smooth surfaces. These arms bifurcate and terminate in irregular twig-like extensions, which interlock with each other to form the mesh. Length of spicular arms varying from 0,27 mm. to 0,74 mm.; and in thickness between 0,067 mm., and 0,135 mm. Surface spicules (Pl. IV, figs. 24—30) composed of spicular discs, more or less lobed and branched, and having a rudimentary shaft. These discs vary in diameter between 0,675 mm. and 1,26 mm.

The mesh spicules of this species are very distinctly marked off from any other of the allied forms by the peculiar ring-shaped swelling with which the arms are furnished. One arm of the spicule extends but a short distance from the central point and then expands into a prominent rounded knob; the other three arms radiate irregularly from the centre, near which each has the ring-shaped swelling, and then rapidly diminishes in thickness and becomes divided into twig-like branches.

The surface spicules which I regard as probably belonging to this species vary in form from discs with a rudely indented edge, to spicules with but a small central disc, from which radiate bifurcate expanded arms. In nearly all the forms there are indications of a shaft, but this is reduced to a very minute point. No indications of canals are exhibited in these spicules but in similarly shaped spicules from the Westphalian Chalk, three small canals are shown radiating from the point of the shaft, and this point is frequently not in the centre of the disc. There are such numerous transitional forms between the spicules with but a slightly indented disc, and those in which there are three main arms with bifurcated extensions, that it is impossible to separate these spicules into discoid and branched forms, but, on the other hand, a distinction can be made between the branched surface spicules with a central disc which I place in Ragadinia, and the branched surface spicules without a central disc and with much narrower arms, which probably belong to the Genus Racodiscula.

The sponges which serve as the type of the Genus *Ragadinia*; R. rimosa, Roem. sp., are platter-shaped bodies with rounded edges and short base. The spicular arms of the type species are very unequal in length and are ornamented with warty prominences similar to those of the G. Plinthosella. Professor Zittel, in his description of the genus, states that there are very numerous specimens in the Upper Chalk of Ahlten in Hanover which had all been referred to one species *R. rimosa*, Roem. but could probably be divided into two or three different species. On comparing the Horstead spicules with mounted specimens of the spicules of *R. rimosa*, in the Palaeontological Museum at Munich I find that they differ in having but a single ring-shaped expansion on the arms and in the absence of the warty projections. There is however a mounted specimen from Hanover, labelled *R. rimosa,* which differed from the other specimens of that species and closely corresponded with the Horstead spicules both in the mesh and surface spicules. I think that this difference is sufficient to indicate that these annulated spicules belong to another species which I propose to name R. annulata.

The mesh spicules of R. annulata are rare in the Horstead material, whilst the surface spicules are very abundant.

Racodiscula and allied Genera.

(Plate IV, figs. 31—34. Plate V, figs. 5—8.)

Spicules of the mesh consisting of four equal or nearly equal smooth arms radiating from a common centre; the extremity of the arms divided up into a mass of small twig-like extensions which are united with the similarly formed extremities of adjacent spicules. Length of spicular arms in different spicules varying between 0,27 mm. and 0,45 mm.; and between 0,045 mm. and 0,067 mm. in thickness. Surface spicules consisting of horizontally expanded, numerously branched delicate heads with short rudimentary shafts. The width of the heads varies between 0,517 mm. and 1,17 mm.

The mesh spicules of Racodiscula and allied genera are very minute in comparison with those of Plinthosella and the slender arms have been so much eroded by fossilization that, notwithstanding they are present in considerable numbers it is difficult to find good specimens. In many examples the spicular arms are reduced to slender threads and their terminations only show the stumpy ends of the fibres which formed the relatively large cushion-like mass by which they were united together. There are several genera of sponges, whose mesh-spicules, with the exception of slight variations in the length of the rays and in the size of the intricate knot at their point of union, are closely similar to each other. This has been shown by Zittel in the spicules of the *fossil* sponges of the genera Phymatella, Callopegma, Turonia and Siphonia (Studien üb. foss. Spong. Taf. VIII, IX). As regards Siphonia also the spicular structure has been well illustrated by Professor Sollas (Quart. Jour. Geo. Soc. 1877. Pl. XXVI). In *existing* sponges a similar form of spicule also occurs in Discodermia, Theonella and Kaliapsis. With such small differences in the structure and form of the spicule, it would be very difficult to determine, even were these free spicules well preserved, how many of these fossil genera may be represented, and it is hopeless to make an attempt to do this, when the spicules, as in the present instance, have been partially destroyed.

The surface spicules (Pl. IV. figs. 31—34 which I regard as belonging to the same sponges as the minute four armed skeleton spicules, differ from those which I have placed under Ragadinia, in the absence of a central laminated disc; the head of the spicule being formed by three horizontally extended sinuous arms which are once, and occasionally twice, bifurcated. There are two well marked varieties in these surface spicules; one form (figs. 31, 32) has the branches very regular and even in width, with an average diameter of the head of 1,1 mm.; the other form is very small and slender and the terminal ends of the branches are deeply laciniated; the diameter of this form is only 0,517 mm. These surface spicules are present in greater numbers and in better preservation than the mesh spicules, but they are also of but little value for determining the particular genus of sponges to which they belonged. To the smaller form (fig. 34) correspond the laciniated spicules which Mr. Carter has described from the Haldon Green Sand under the name of *Dactylocalycites Vicaryi* (An. Mag. N. H. Vol. 7, p. 123, Pl. VII, figs. 1,2). The larger form (figs. 31,32) is nearly double the size of the similarly shaped spicule from the Upper Chalk of Westphalia, figured by Prof. Zittel. (Ueber Coelop. Taf. VII, figs. 29, 30).

Dermal spicules of Lithistids.

(Plate III, figs. 11, 12, 15).

Compound trifid spicules with relatively short, straight or slightly curved, pointed shaft and with spreading head-rays. There are three forms of these spicules, small in comparison with the trifid spicules belonging to Geodia, and probably belonging to different species of sponge. The first (fig. 11) has the shaft curved and the primary head rays also curved and directed upwards; they bifurcate into very small pointed secondary rays. An average spicule is 0,675 mm. in length and the thickness of the shaft 0,056 mm. In the second form (fig. 12) the shaft is straight and pointed, the primary head rays are very long in proportion to the shaft and directed forward and the secondary rays are similarly long, divergent, and projecting upwards. Total length of the specimen figured 0,787 mm. diameter of shaft 0,045 mm.; width across head rays 0,675 mm. This form has been found also in the Irish Chalk, (Wright: op. cit. Pl. II, fig. 16). The third form (fig. 15) has also a straight shaft but the rays are very short and pointed, and they bifurcate so close to the top of the shaft that the primary ray can scarcely be distinguished. The length of the specimen figured is 0,99 mm. thickness of shaft 0,056 mm.

As regards their dimensions, these spicules correspond much closer with the trifid spicules which are present as surface spicules in different genera of Lithistid sponges, than with the trifid zone spicules of Geodia, and it seems to be very probable, that they are allied to the surface spicules of *Corallistes*, O. Schmidt.

Dermal? spicule of Lithistid?

(Plate I, figs. 29, 30)

Spicule consisting of a slender, more or less elongated, nearly cylindrical shaft, having at one extremity four elongated slender tapering arms, spread out in a plane at right angles to the shaft and united together near the shaft by a solid siliceous membrane. The angle embraced by the four arms varies between 80⁰ and 135⁰ in different specimens. Only traces of canals are shown in the Horstead specimens but in similar spicules from Coesfeld, they are present both in the rays and shaft, and unite at the junction of these. I have not yet met with a complete specimen, but the arms appear to have been of equal length; the longest which I have seen is 0,9 mm. The longest shaft met with is 0,787 mm. with a thickness of 0.056 mm. In all the specimens the connecting membrane between the arms is only developed but a short distance from the shaft. The spicules are somewhat rare.

No spicule at all resembling this has been met with in any recent sponge and its affinities are very doubtful. The number of the rays remove it from relationship with Tetractinellid sponges as also with surface spicules of the known Lithistids. It is possible however that it may be the surface spicule of a Lithistid sponge as there is a great diversity known to prevail in the outer spicules of this group. This spicule was first noticed in the Chalk of the North of Ireland (Wright: op. cit. p. 90, Plate III, figs. 1 a, b.) and Dr. Bowerbank expresses the opinion that it is 'from the expansile dermal system of a siliceo-fibrous sponge'. Professor Zittel has also figured several examples of the same spicule from the Upper Chalk Formation of Coesfeld (Ueber Coelop. p. 46 Pl. V. fig. 47—50).

Order Hexactinellidae, Oscar Schmidt.

The sponges of this order are built up of spicules composed of six rays which form three axes crossing each other at right angles. In each ray there is a distinct canal which unites with those of the other rays in the centre of the spicule. There is an enlargement, in many instances, in the centre of the spicule, which is either formed by a thickening of the silica of each ray at the point of junction; or by the giving off of slight buttresses from each ray which unite together and form as it were a framework, of the figure of a hollow octahedron, to inclose the junction of the canals of each ray, in the centre of the spicule. To this latter structure the term ‹ lantern › node has been applied. In addition to these spicules of the skeleton there are in the living examples of the order very minute 'flesh' spicules of wonderful variety and beauty of form, but in the fossil sponges these have not been preserved. The skeleton of the Hexactinellid sponges is either built up of spicules which are merely connected together by the sarcode or else the spicules are welded together by the extremity of their rays to form a connected mesh-work with regular oval or oblong interspaces. The hexactinellid sponges are also provided with an exterior surface layer, composed of a delicate perforated siliceous membrane which, in some instances at least, can be seen to be formed by a modification of spicules similar to those of the interior skeleton. In some species too the sponge was anchored to the sea bottom by elongated thread-like spicules terminated by small anchor-shaped heads.

In this Horstead flint the hexactinellids are represented by free spicules of various sizes; by small portions of the spicular mesh of different species, also by fragments of the surface membrane and by portions of the root-fibre and the small terminal anchors. The free spicules appear to belong to sponges of the group of the Lyssakina in which the spicules were only connected by sarcode. Fragments of the mesh-work of the group of the Dictyonina are not infrequent and occur oftener than in the case of the Lithistid sponges, which may be accounted for by the fact that the skeletal mesh of the Hexactinellids is formed by a complete welding together by silica of the adjacent spicular arms, and not, as in the Lithistids, by a mere interlocking of their extremities.

An approximation to the affinities of these fragments of the skeleton may be made by a comparison of the regular or irregular disposition of the mesh, its dimensions and form, and by the solid or hollow characters of the central axis of the spicules. Reliable indications are also furnished in some instances by the surface membrane, and the connection between this outer membrane and the interior skeleton is occasionally shown by fragments in which a layer of the interior skeleton spicules yet remains attached to the surface membrane. Unfortunately most of these hexactinellid fragments have been injured by the fossilization; the interior canals have been obliterated, the small processes forming the lantern knots have been worn through, and the spicular arms have been so eroded that it is difficult to tell definitely whether they were originally smooth or spinous.

Sub-order Dictyonina, *Zittel.*

Genus Leptophragma, *Zittel* 1877.

Leptophragma sp.

(Plate V, fig. 17).

The disposition of the spicules of the mesh is irregular so that the interspaces are either oblong or triangular. The central node of the spicules is solid and but slightly enlarged. Average thickness of the arms of the spicules 0,078 mm., length of the more regular openings of the mesh 2,25 mm.; width 1,23 mm.

The solid knot of the spicules and the form and arrangement of the mesh correspond with the structure of a species of *Leptophragma*, from the Upper Chalk of Vordorf in Brunswick, but the diameter of the mesh in the Horstead examples is nearly twice that of the Vordorf sponge. The hexradiate form of the spicules is frequently obscured by the attachment of some of the spicules in an irregular manner to each other, so that some spicules appear to have seven arms radiating from the central node instead of the normal number. The sponges of this genus are cup shaped with a thin surface membrane which is provided with regularly disposed canal openings. Fragments of the skeleton are not uncommon and are readily distinguished from all the other hexactinellid remains in this flint by the large size of the mesh as well as by its irregular arrangement.

Leptophragma sp.

(Plate V, fig. 18).

Mesh work of the skeleton arranged so as to form triangular and quadrangular interspaces. The central knot of the spicule solid and expanded to about twice the thickness of the arms. Average diameter of the mesh 1,09 mm.; thickness of the arms of spicule 0,04 mm.; of the central node, 0,09 mm.

The much smaller size of the mesh work and the inflation of the central node of the spicule distinguish these fragments of sponge from the preceding form.

Craticularia sp.

(Plate V, fig. 19).

Mesh skeleton very regular and disposed so as to form quadrangular interspaces. The central nodes are solid, and but slightly larger than the spicular arms. Thickness of the arms 0,033 mm.; diameter of the squares or distance between the nodes 0,2 mm. Rare.

In the regularity and form of the interspaces of the mesh and the character of the nodes, this sponge bears a great resemblance to specimens of *Craticularia* from Streitberg which are in the Museum at Munich. Prof. Sollas has also described a somewhat similar skeletal mesh in *Eubrochus clausus* from the Cambridge Coprolite-bed. Geo. Mag. 1876. p. 398, Pl. XIV).

Cystispongia sp.

(Plate V, figs. 20, 21).

The skeletal mesh is formed of spicules with relatively short arms and large sub-spherical solid nodes. The arrangement of the skeleton is very irregular. Distance between the nodes 0,225 mm.; thickness of spicular arms 0,033 mm.; diameter of central node 0,11 mm. In addition to these fragments there are others with the spicular arms much closer arranged which appear to be dermal portions of the same sponge. The remains of this sponge are more abundant in the Horstead flint than those of any other Hexactinellid.

The only Cretaceous sponges with which these fragments can be compared are those of the Genus Cystispongia, Roemer, Figures and description of *Cystispongia (Cephalites) bursa,* Quenstedt, sp. are given by Prof. Quenstedt in his work on ‹Die Schwämme p. 492, Taf. 138, fig. 17 and I have had the opportunity of comparing examples of this species with the Horstead fragments. *C. bursa* is usually of an oval form, the outer surface is composed of a very delicate lamina of silica, immediately beneath which is a layer of closely arranged spicular mesh work with large spherical nodes, much resembling that of my fig. 21. Within the oval-shaped case of silica there are thin folded layers made up of spicular meshes, but the solid spherical nodes are not so large in proportion to the arms as in the Horstead examples. I have discovered at Horstead fragments of lamina not unlike that forming the exterior membrane of Cystispongia, but none of these fragments had any portions of the spicular mesh attached, so that it is doubtful whether they really belong to this genus of sponge, but the resemblance of the fragments of the skeleton is so close that it seems highly probable that they belong to Cystispongia. There is also a remarkable resemblance between these fragments of mesh and the skeleton of *Astylospongia praemorsa.* Goldfuss and under the microscope there was little difference to be noticed in the dimensions, form, and arrangement of the spicular mesh of this Silurian sponge, and the examples from the Upper Chalk.

Coscinopora sp.

(Plate V, figs. 22—24).

Portions of skeletal mesh having circular or elliptical interspaces of unequal dimensions; composed of the usual six-rayed spicules with open or ‹ lantern › nodes at their centres. Diameter of some of the larger interspaces 0,45 mm. Fragments of outer or surface layer consisting of a delicate membrane perforated with circular openings of different sizes, the larger, which appear to be disposed at regular distances from each other, have a diameter of 0,38 mm. Fragments of the root-fibre composed of nearly straight spicular fibres with transverse connections.

These different portions of the structure of a Hexactinellid sponge appear to correspond with the Genus *Coscinopora* Goldfuss. The type of the genus *C. infundibuliformis,* Goldf. (Petref. Germ. 1[te] Theil, p. 30, Taf. 30, fig, 10) is a cup shaped sponge with thin walls, which are covered by a delicate perforate surface membrane similar to that of fig. 23. The inner skeleton has spicules with ‹ lantern › nodes, forming elliptical interspaces, which however are less regular in their arrangement than in the Horstead examples (fig. 22). The sponge appears to have been attached to the sea bottom by a root-like extension of the base, which is formed of nearly parallel fibres of silica with transverse connections at frequent intervals similar to that shown in fig. 24. *Coscinopora infundibuliformis* appears to be abundant in the Upper

Chalk Formation at Coesfeld in Westphalia. Good illustrations of the structure are given in Zittel's «Handbuch der Palaeontologie» p. 175.

Ventriculites? sp.

(Plate V, figs. 25, 26).

Skeletal mesh work composed of spicules with stout arms and comparatively large open or «lantern» nodes, the interspaces are nearly circular. Distance from node to node 0,33 mm. Thickness of the arms 0,05 mm.; and of the central «lantern» node 0,15 mm. Fragments of surface layer with irregularly disposed circular pores.

The skeletal mesh of this form may be readily distinguished from the preceding by the stouter arms, the smaller and nearly circular interspaces, and their more regular arrangement. These differences appear sufficient to show that there are in this Horstead material two different species of hexactinellid sponge with the open or «lantern» nodes. I am, however, uncertain whether these fragments properly belong to the genus Ventriculites, for the mesh has a much more regular arrangement than in any of the specimens of Ventriculites which I have seen, and corresponds closer with the mesh of the allied Genus Pachyteichisma, Zittel. As however the Genus Ventriculites is known to occur in the Norfolk Chalk, I prefer to place these fragments provisionally under it.

Sub-Order Lyssakina, Zittel.

In this division of the hexactinellid sponges the spicules are not welded together by the extremities of the arms, but are merely held together by the sarcode of the living animal. Consequently in the fossil condition, the spicules are as a rule detached from each other, though occasionally the form of the sponge is still retained.

Stauractinella cretacea, n. sp.

(Plate V, figs. 9, 10, 10a, 11).

Large free hexactinellid spicules, arms mostly straight, nearly of an equal thickness throughout or very gradually tapering, one axis frequently much longer than the others; the central node solid and but slightly, if at all, inflated. Extreme length of spicular arms 2,18 mm.; thickness 0,112 mm. Abundant.

Spicules with the above characters are numerous in the Horstead flint and from their dimensions and isolated condition appear to belong to the sub-order Lyssakina. In one instance however, I have met with an example (fig. 9) in which two spicules are apparently connected, but as the arms of one are very short, it may be merely a case of abnormal growth. The majority of these spicules have one axis much longer than the others, but in none of the examples are the extremities of the spicular arms complete, and it is quite possible that they may have extended in an attenuated form to a considerable length, and would have then presented a greater resemblance to the spicules of the existing sponges of this sub-order. One spicule (fig. 10 a) differs from the rest in having one arm truncated and rounded a short distance from the node, and the other arms are thinner and pointed. The interior canals of these spicules are but rarely preserved, when present they are of an abnormal width.

The relationship of these free hexactinellid spicules appears to be very near to *Stauractinella jurassica*, Zittel (Studien über fossile Spong. p. 60) in which similarly shaped, but much larger spicules than these from the Chalk Strata, form the skeletons of large spheroidal sponges. As they are readily distinguished from the jurassic forms, I propose to name the sponge to which they belonged Stauractinella cretacea. A similar spicule, but so far as I can judge, of much smaller size has been found in the Chalk of the North of Ireland (Wright: op. cit. Pl. III, fig. 4).

Genus Hyalostelia, Zittel.

(Handbuch der Palaeontologie p. 185).

Hyalostelia fusiformis n. sp.

(Plate V, fig. 12—16).

Free hexactinellid spicules having one axis much longer than the others, arms straight or but slightly curved, and gradually tapering to a point. The centre of the spicule solid and inflated. Very variable in their dimensions. The longer axis of the larger spicules is 1,05 mm. in length; and the central node 0.18 mm in thickness. A small spicule is 0,45 mm. long; and the central node 0,09 mm. in diameter. These spicules are distinguished from the preceding form by the rapid tapering of the arms and the prominent inflation of the central node. In some examples the arms of the spicule are fusiform, and they have the aspect of three robust acerate spicules joined together at right angles; in others, the central node is more of a spheroidal character and the arms are more distinctly marked off from the centre. The smaller spicules are more numerous than the larger in the deposit.

The forms nearest to these spicules are those which have been described by Messrs. Young from the Carboniferous strata in Scotland under the name of *Hyalonema Smithii*, (An. Mag. Nat. Hist. S. 4, Vol. 20, p. 425, Pl. XIV). The Horstead specimens are however much more regular in their form, as well as much smaller than the Carboniferous spicules. The peculiar fusiform inflation of the central node marks these spicules off very clearly from those of any known fossil and recent species of this sub-order.

A spicule approximating in size to the smaller of my specimens has been figured by Mr. Carter from the Haldon Green Sand (An. Mag. N. H. S. 4, Vol. 7, p. 123, Pl. VII, fig. 15) and he compares it to the silicified fibre of the Euplectellidae. A spicule with inflated node but with the arms of an even thickness throughout has also been found in the Irish Chalk. (Wright: op. cit. Pl. III, fig. 5.) Dr. Bowerbank has also delineated a spicule from the existing sponge *Euplectella aspergillum* Owen, (Monogr. Brit. Spong. Vol. I, p. 257, Pl. VIII, fig. 174) which somewhat resembles the larger spicules from Horstead, but it is only about one-fourth the length and the central inflation is not so pronounced.

Anchoring Spicules of Hexactinellids.

(Plate I, figs. 31—36. Plate V, figs. 27.)

Mostly small spicules with elongated shaft and variously shaped head from which 4, and in one instance 6 rays or barbs project backwards. There are present in the Horstead flint several different forms of these anchor spicules which are all characterized by a more or less inflated head and a shaft which is short in all the examples preserved, but may originally have been extended. One of these forms (figs. 34, 36) has a very slender shaft and the head shaped like a four-sided pyramid from the base of which four minute rays project backwards. The shaft in some of these spicules appears to have been when complete short and pointed and it is doubtful if these anchor spicules really belong to Hexactinellid sponges. Length of these spicules 0,40 mm; average width of head 0,112 mm. In another form of spicule (figs. 33, 35) the head has the form of a cone, from the base of which four or six minute rays project backwards at an acute angle with the shaft. An example of this form (fig. 33) has a length of 0,607 mm. and the width of the head is 0,18 mm. A third form (figs. 31. 32) has a more robust shaft than the others, and the head is obtusely rounded with four curved arms radiating from it like the ribs of an umbrella. In one specimen, the length of the incomplete spicule is 0,517 mm. and the expansion of the head rays 0,45 mm. The shafts of all these spicules appear to have been smooth but there occur fragmentary spicules (Plate V, fig. 27) consisting of a straight nearly cylindrical shaft from the surface of which numerous minute recurved spines project, which probably are the shafts of anchoring spicules. Both the anchoring spicules and the spinous shafts are very rare.

The resemblance of these anchoring spicules to those of existing sponges of the sub-order Lyssakina is sufficient to prove that they belonged to this group, and not improbably to the same sponges as the free hexactinellid spicules already described. A comparison may be made with the figures of several kinds of anchoring spicules of existing sponges given by Mr. Carter (An. Mag. Nat. Hist. S. 4, Vol. 12, Pl. XIV) also with those of *Rossella antarctica*, Carter (An. Mag. Nat. Hist. S. 4. Vol. 9, Pl. XXI). Similar shaped but larger anchoring spicules also occur in *Hyalostelia (Hyalonema) Smithii* Young and Young (An. Mag. Nat. Hist. S. 4, Vol. XX, Pl. XIV) and more recently Mr. Carter has found them fossil in carboniferous strata near Sligo in Ireland (An. Mag. Nat. Hist. S. 5, Vol. 6, p. 211, Pl. XIV, fig. 9). Mr. Wright has also figured a small four armed anchoring spicule with spinous shaft from the Irish Chalk (op. cit. Pl. II, fig. 23 a, b).

Spicules with Borings.

(Plate V, figs. 28, 29).

Out of several hundreds of sponge spicules from Horstead which I have examined under the microscope, there are a few which give distinct evidence of having been perforated by some organism. The perforations are of the form of simple, unbranched, elongated, cylindrical tubes extending for various lengths in the interior of the shafts of acerate and trifid spicules. The tubes are sometimes curved and smooth, but occasionally they are convoluted and twisted. They terminate blindly in the interior of the spicule. In some instances the tube apparently commences in the centre of the broken end of a spicule, where the canal in the perfect example would be situated and from thence it extends forwards in the substance of the spicule without any regularity, occasionally keeping near the centre or wandering towards different parts of the circumference, without however penetrating the outer wall of the spicule. The interior is apparently filled with a transparent material of a light greenish tint, giving no colour under the polariscope and apparently destitute of any granular particles. The longest of the tubes noticed is 1,8 mm. and the width varies in different specimens between 0,033 mm. and 0,067 mm.

The mineral character of the spicules in which these borings occur is precisely similar to the normal ones of this material, that is to say, it is now of chalcedonic silica and there seems no reason to doubt that the chalcedonic silica has been produced from the conversion of the original amorphous silica of the sponge spicule, so that these perforated tubes whether made previous or after the change, have been constructed in siliceous material. The peculiar form of the perforations show that they have been produced by the action of some living organism, of which no other traces are left. These tubes are larger than those which have been described by Prof. Duncan in the substance of Silurian and Tertiary corals, and attributed by him to the boring influence of a parasitic alga, *Palaeachyla perforans* (Quart. Jour. Geo. Soc. Vol. XXXII, p. 205) neither are they branched or filled with the dark granules which appear associated with the borings in the corals. There is further the peculiarity that they have been made in siliceous structures.

Summary.

On account of the detached and free condition, in which most of the sponge spicules here described, are met with, it is apparent that nothing more than an approximate estimate can be formed of the number of species and genera which are represented in the contents of this flint. A certain degree of accuracy can be obtained in the case of many Lithistid and Hexactinellid sponges in which the peculiar form of the individual spicules and the not seldom instances in which these remain together, mark off one species from another; but in the case of Monactinellid and Tetractinellid sponges in which only isolated spicules are met with, and are often closely alike in different species, there is great difficulty in deciding to how many species the various spicules may belong. Making due allowance for this fact, I estimate that the 160 different *forms* of spicules which are here described and figured from the cavity of this one chalk-flint belong to 38 species and 32 genera of sponges. These are divided into 4 species of 3 genera of Monactinellid sponges; 20 species of 7 genera of Tetractinellids; 6 species of 5 genera of Lithistids; and 8 species of 7 genera of Hexactinellids. Whatever may be the opinion as to the validity of so many species and genera, no doubt can remain that these spicules and fragments of sponges which are thus mingled together in one locality and in so small a quantity of material, bear incontrovertible evidence of a very great development of the different orders of sponges in the English Chalk. As the preservation of these spicules depends so much upon their capacity to resist the eroding influences of fossilization which adversely affects the minuter forms far more than the larger, too much stress cannot be laid upon a calculation of the relative abundance of the different orders of sponges, from the spicules which have escaped destruction. To some extent the great number of species of the Tetractinellid sponges, which are more numerous in this material than those of the other orders put together, may be due to the fact that the zone and body spicules of this order are unusually robust, and would thus be more likely to be preserved than the smaller spicules of other sponges. But even allowing for this, the Tetractinellid sponges appear to have predominated, and next to them the Lithistids and. Hexactinellids are in about equal numbers, whilst the Monactinellids, so far as can be determined, are few and unimportant. It may perhaps be deemed improbable that such a number and variety of sponges should be mingled together in such a small quantity of material but similar instances of the occurrence of great numbers of sponges together have also been discovered in modern deep-sea dredgings. Thus for example; Sir W. Thomson records that in one haul of the dredge in the North Atlantic there were brought up forty specimens of vitreous sponges (An. Mag. Nat. Hist. 1869, p. 119) and now lately, in material from the Gulf of Manaar in the Indian Ocean which in quantity would hardly fill a quart measure; Mr. Carter has described no fewer than 62 species of sponge (An. Mag. N. H. S. 5, Vol. 6, p. 457); so that the contents of this chalk-flint are to some extent parallelled by the deposits of the present oceans.

It is doubtful whether any precise conclusions as to the depth of the ocean in which these chalk sponges existed, can be drawn from comparing them with existing sponges whose bathymetrical limits have been asertained, on account of the great limits within which sponges of the same genus oftentimes appear to exist. At present the results of the investigations of the sponges of the Challenger expedition are not known, but recent investigations of the Atlantic sponges by Mr. Carter and those from the Gulf of Mexico by Oscar Schmidt show that the previous ideas as to the depth in which different orders of sponges exist, have to be considerably modified. The Monactinellidae and Tetractinellidae were formerly regarded as inhabiting comparatively shallow waters, but it is now ascertained that they extend to depths previously thought to be exclusively inhabited by Lithistidae and Hexactinellidae; whilst, on the other hand, some representatives of these latter are now known to exist in but moderate depths. Two or three examples may be given of the depths in which existing sponges nearly allied to those in the chalk, have been discovered. A species of Pachastrella, *P. amygdaloides*, Carter, whose spicules most closely resemble some in the Chalk flint, exists in the Atlantic at a depth of 1752 feet; *Lyidium torquilla*. O. Schmidt to which the chalk spicules of the same genus are nearly allied, also exists in the Atlantic, off the coast of Cuba, at a depth of 1610 feet; Lithistid sponges nearly allied to *Racodiscula* occur at varying depths between 720 feet and 1620 feet; the Hexactinellidae are most abundant in depths between 1800 and 6000 feet, but a species of Cystispongia a genus also represented in the Chalk flint is recorded by Oscar Schmidt (Spong. d. Meerbusen von Mexico) as existing at depths varying between 120 feet and 1752 feet. So far as these comparisons extend, the sponges of this chalk flint may have inhabited depths of 1700 feet.

The great resemblance which is presented by these Horstead sponge remains and the spicules which have been described from the Haldon Green Sand; the Upper Chalk of the North of Ireland, the Chalk Formation of Westphalia, and the Eocene Sand of Brussels shows that these sponges had a wide distribution both in space and time. In the Eocene strata of Brussels there occur many forms of spicules which are not found at Horstead; but with few exceptions in this single Horstead flint, there are present *all* the detached forms of spicules which have been found both at Haldon and in Ireland and Westphalia. Of the 34 different forms of spicules from the North of Ireland which were obtained from the contens of hollow flints from 36 different localities all the forms except one are met with in the single flint at Horstead. Detached sponge spicules are also known from the Upper Chalk in the South East of England but up to the present, so far as I am aware, no published description has been given of them. The few sponges described hitherto from the Upper Chalk of England belong to the Lithistidae and Hexactinellidae whose more or less complete skeletons occur in a few localities, but are by no means generally distributed. From these sparsely distributed specimens no one would be justified in stating that the sponges played an important part in the building up of the Upper Chalk of England. And even at Horstead one would be extremely fortunate to find a fragment of sponge skeleton in the Chalk itself. Yet in this same locality the contents of this hollow flint make it manifest that sponge life was equally as abundant and varied, and contributed as great a share to the deposits of the cretaceous ocean as these organisms do to the present deep-sea deposits in the Atlantic. The perfect state of preservation, not only of the sponge spicules, but also of the tender shells of foramenifera and ostracoda which in marvellous variety of form are all mingled together in the cavity of this flint, proves that this flint meal contains a fair sample of the organisms which originally formed the cretaceous ooze, if we except however the coccoliths which are not preserved. Subsequent metamorphism has altered this ooze, filled with perfect organic remains, into the present beds of Chalk and layers of flint nodules. As already noticed, the organic remains in the flint meal have not altogether escaped a certain degree of alteration, which has affected their mineral constituents, but has stopped short of destroying their forms or dissolving them. A study of these fossils thus wonderfully preserved enables us rightly to interpret the changes which have taken place in the production of the chalk and flints out of the cretaceous ooze. The foramenifera, ostracoda, and other small organisms whose skeletons are formed of carbonate of lime have been for the most part so crushed and broken up by the mechanical pressure to which they have been subjected, that though the fragments are sufficient to indicate their former existence, it is only here and there under special circumstances that their skeletons are found complete in the chalk. A still more complete change awaited the skeletons of the sponges. These structures, after the death of the animal, appear largely to have fallen apart into their constituent spicules, and though composed of silica, which till lately was regarded as more stable than carbonate of lime, they were so completely dissolved and removed from the chalk that an analysis of this material in which they flourished, does not yield a trace of silica to show their former presence in it. The silica resulting from the solution of these sponges became aggregated to form the nodules of the flints or was deposited in the joints and fissures which intersect the chalk strata in many places. In the same proportion as the chalk indicates the remains of the foramenifera, ostracoda, and other organisms with calcareous skeletons, so also do the imbedded nodules and masses of flints bear witness to the siliceous skeletons of the sponges which contemporaneously existed with them. This may appear a somewhat far-reaching conclusion to arrive at from the presence of these sponge spicules in this single chalk flint but evidence from other quarters corroborates and strengthens it. Mr. Wright's investigations in the material inclosed in chalk flints from various places in the North of Ireland prove that there also siliceous sponges abounded mingled with the shells of foramenifera and other calcareous organisms, whilst in the chalk itself, which has there been metamorphosed into a hard limestone, no traces of sponges remain, and nearly all recognizable fragments even of the calcareous organisms have been obliterated. It is possible that a small portion of the silica of the flints may be derived from other organisms such as the Radiolaria; but up to the present the only two or three forms of this group known to exist in the Chalk formation have been discovered by Prof. Zittel in strata in Westphalia teeming with unaltered sponge spicules; and so far as known at present the Radiolarians had but a slight development in the cretaceous ocean.

The hypothesis of the derivation of the flints in the chalk from the silica of sponge skeletons is by no means a new one, but it has not hitherto been generally accepted from the absence of *proof* of the existence of sponges in sufficient numbers to furnish silica for the great mass of flints with which the chalk is filled, and from the difficulty of explaining the arrangement of the flints in nodular layers. Even in the last edition of the Students Elements of Geology published in 1871, Sir Charles Lyell attributed the chalk flints to the dissolved shells of diatoms which at certain periods swarmed in the cretaceous ocean and were alternately replaced by the foramenifera which supplied the material for the chalk. Within this present year the origin of the cretaceous flints has been made the subject of a paper by Dr. Wallich. (Quart. Jour. Geo. Soc. 1880, p. 68). This able investigator brought no evidence to show the general distribution of the sponges in the cretaceous ocean, but merely based his argument that the flints were derived from sponge skeletons, on the fact, that siliceous sponges are found abundantly in the deep sea dredgings of the Atlantic, and that on the assumption of their being present in similar numbers in the Chalk ocean, they would have been able to furnish the silica for the flints. The contents of this flint from Horstead and of those from the North of Ireland, prove, what Dr. Wallich assumed, that in its original condition the cretaceous ooze was, like that of the Atlantic deep sea mud, filled with the spicular skeletons of sponges. At the same time they furnish no evidence of the hypothesis of Dr. Wallich that alternating periods are established during which one of the two predominant animal types (Foramenifera and Sponges) gradually overwhelms and crushes out the other over indefinite local areas, the strata of the chalk in the one case and the intercalated flint beds in the other, being the issue of these contests. (op. cit. p. 72) The contents both of the Irish and Horstead flints show that the sponge spicules are equally as much intermingled with foramenifera and other calcareous organisms as in the Atlantic ooze, and that therefore both these »animal types« flourished contemporaneously without alternately choking the life out of each other.

These hollow flints throw no fresh light upon the causes which have brought about the arrangement of the nodules in definite layers but the perfect state of preservation of their contents show that in certain cases at least they were formed before there was any great accumulation of overlying material, which would have crushed the tender shells inclosed within. But whatever may have been the forces which dissolved and re-deposited the silica in its present form, it seems evident that the delicate skeletons and spicules of sponges have been the original source of the material itself.

Postscript.

Whilst this work was going through the Press, I received from Professor Sollas, a separate copy of his paper on the *Flint Nodules of the Trimmingham Chalk,* which appeared in the November and December numbers of the Annals and Magazine of Natural History. In this paper, Prof. Sollas has described different forms of sponge spicules derived from material of the same character, in all essential respects, as that from Horstead. So far as one can judge from the outlines of the spicules in the accompanying plates, they are, with few exceptions, of similar forms to those which I have herein described, as also to those from the Chalk of Westphalia and the North of Ireland, figured by Zittel and Wright respectively. The Trimmingham nodules, however, on the supposition that they have been thoroughly searched, do not contain anything like the variety of spicular forms which are present in the Horstead flint. Prof. Sollas has placed then under 17 genera, of which no fewer than 13 are *new;* whereas I have placed the far greater number of spicules from Horstead, including nearly all the forms present at Trimmingham, under genera already known, to which they appeared closely allied. As these spicules so nearly resemble those of sponges already described, I am unable to see either the necessity or advantage of instituting new genera to contain them, and have therefore grouped under one genus, spicules, which Prof. Sollas has placed under two or three genera.

The well-marked manner in which the skeleton of Lithistid sponges is built up by the interlocking of the modified arms of the spicules, distinguishes this group so clearly from that of the Tetractinellidae that it is difficult to see why it should be relegated to merely sub-ordinal rank, as has been done by Prof. Sollas. The analogy of the Lyssakine and Dictyonine Hexactinellidae does not hold good with respect to the Lithistidae and Tetractinellidae; for the Lithistid skeleton is not formed by the mere welding together of the usual spicules of Tetractinellid sponges, but the spicules themselves materially differ. It is true that, not infrequently, detached trifid and quadrifid spicules occur in Lithistid sponges and show a near relation between the two orders; but in the same manner, simple monaxial spicules are present in all the orders of siliceous sponges, without being regarded as sufficient reason to group them all as mere sub-divisions of the Monactinellidae.

Prof. Sollas has stated (loc. cit. p. 393) that certain forms figured in Prof. Zittel's Monograph on *Coeloptychium* (Taf. V figs. 11, 12, 17) as sponge spicules, are only casts of foramenifera. In this he is most certainly under a mistake, for such is the beautiful state of preservation of the sponge remains from the Westphalian Chalk, that a novice would be able to distinguish a sponge spicule from the cast of a foramenifer.

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All the figures are drawn by means of the Camera lucida.

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PLATE II.

All the figures on this plate are drawn to the scale of 20 diameters by means of the Camera lucida.


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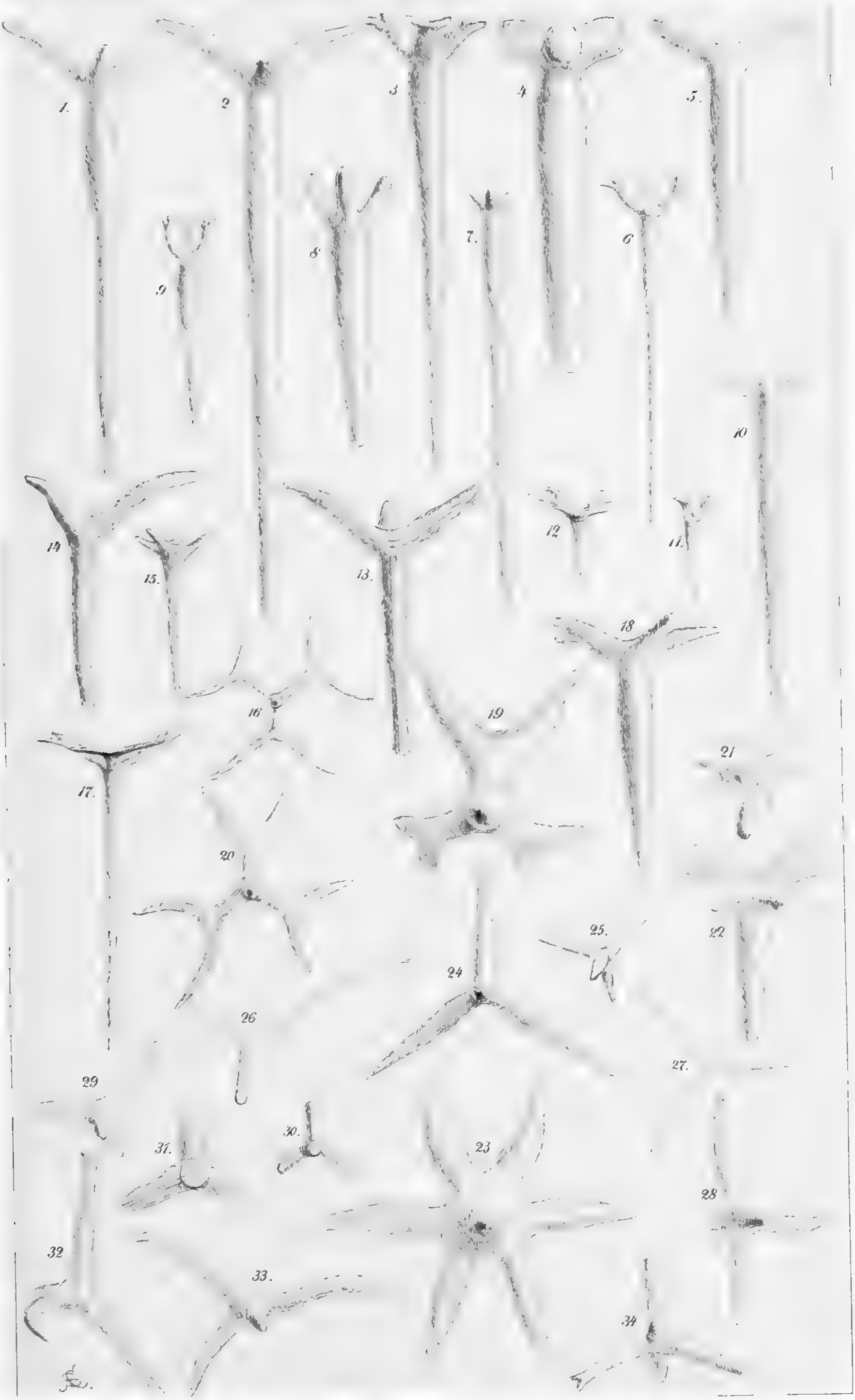
PLATE III.

All the figures are drawn by means of the Camera lucida and to the same scale of 20 diameters.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All the figures on this Plate are drawn to the same scale of 20 diameters by means of the Camera lucida.

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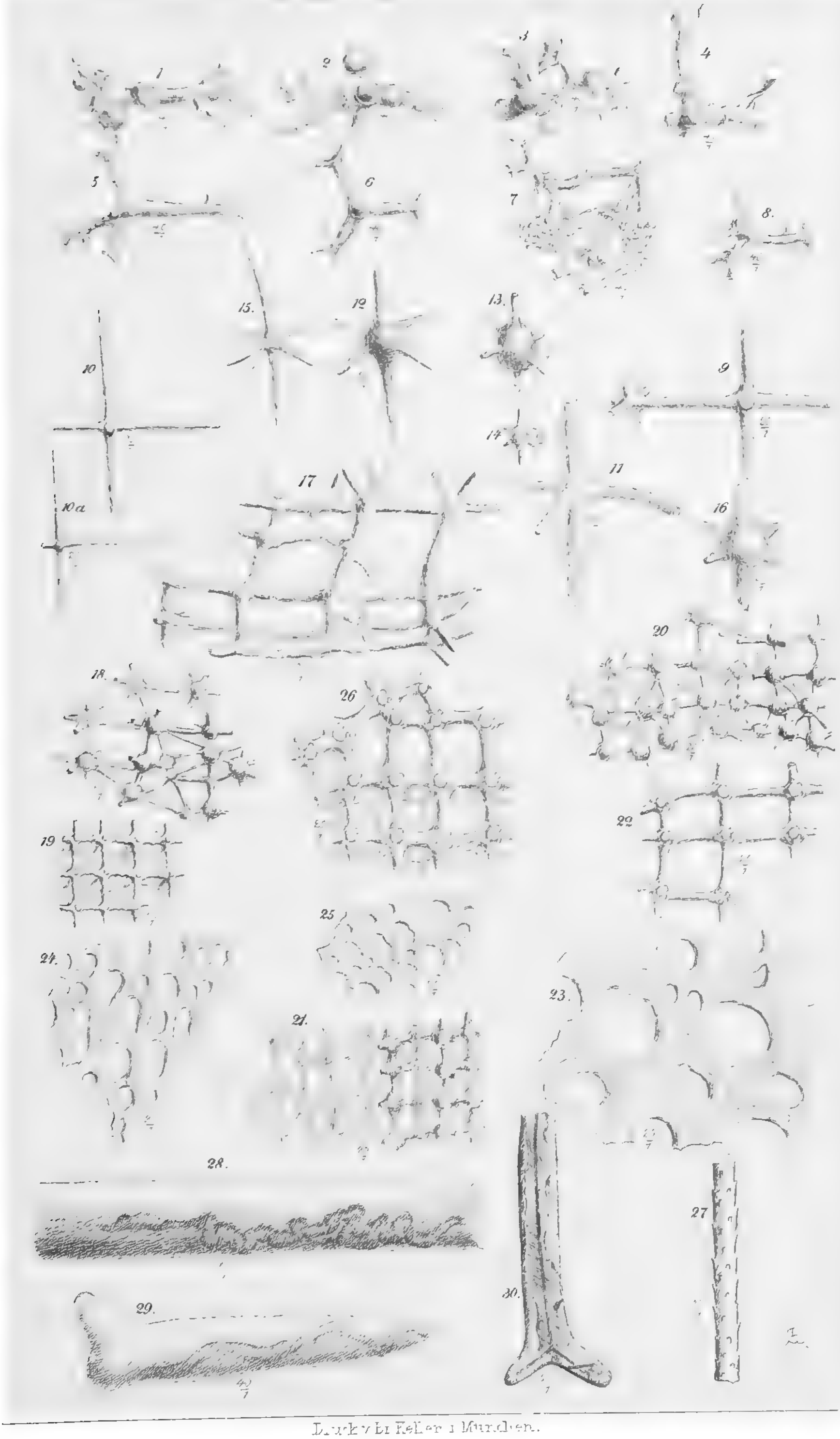
Figs. 1—8, 28, 29 are drawn to the scale of 40 diameters the rest of the figures are on the same scale of 20 diameters. All are drawn by means of the Camera lucipa.



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