Belfast, in an opposite direction from Donegal Square. Leaving town for some time on the following day, I had not any further opportunity of witnessing the interesting phænomenon.

"W. Thompson."

IV.—*On the spongeous origin of Moss Agates and other siliceous bodies.* By J. S. Bowerbank, Esq., F.G.S.*

[With Three Plates.]

In the course of the last session I had the honour of submitting to the Geological Society a paper "On the structure and origin of the flinty bodies of the chalk and greensand formations of England," in which I endeavoured to prove that the greater portion of these siliceous masses were derived from the silicification of spongeous bodies which existed at the bottom of the sea at the periods of the deposit of these strata in as great abundance as their recent types are now found in the ocean, both in tropical and temperate latitudes. In my description of the organic contents of the flints and cherts there described, I mentioned the frequent occurrence of spicula among these remains. From their appearance in bodies which bore every appearance of being true keratose sponges in which spicula were not at that time thought to exist, I was led to believe that the sponges which had originated these siliceous masses were an order of the tribe differing from our recent keratose types only by the possession of siliceous spicula, and therefore, although not absolutely belonging to the same genus as the sponges of commerce, yet so nearly allied to them in every other respect as to leave no reasonable doubt of the true spongeous nature of the fibre that abounds in them. Since that period I have received from my friend Rupert Kirk, Esq., of Sydney, numerous specimens of at least three distinct genera of sponges, and among them many keratose ones, which upon examination with a microscopic power of 500 linear, proved to contain siliceous spicula in great quantities. This circumstance induced me to suspect their presence in the sponges of commerce, and upon examining them carefully I detected spicula in each of the two species from the Mediterranean as well as in that from the West Indian Islands, although, I believe, every author who has hitherto described the sponges of commerce has denied their existence in these bodies. Since the publication of these facts, I have had the opportunity of examining two species of keratose sponges in the collection at the British Museum, which are preserved in spirit in the state in which they were immediately after being taken from their native element, and in both these specimens

* Read before the Geological Society of London, April 7, 1841.

the interstices of the horny fibre are filled with a semipellucid fleshy matter, in which numerous spicula are found imbedded. I will not enter into a lengthened detail of the investigations of these recent forms, as they have already been given to the public in two papers. The first "On the keratose sponges of commerce," I had the honour to read before the Microscopical Society of London on the 27th of January 1841*, and the second "On the structure of a keratose sponge from Australia," is published in the 'Annals and Magazine of Natural History,' April 1841. It is necessary to state thus much, as the discovery of siliceous spicula in recent sponges removes the discrepancy that appeared to exist between the recent and the modern types of a portion of the animals under consideration. The fibre in all the sponges of commerce, as well as in many keratose species from Sydney, that I have examined, is solid; but in one species, *Spongia fistularis*, Lamarck, described by Dr. Grant in the 'Edinburgh Philosophical Journal,' vol. xiv. p. 339. the structure is truly tubular; and this is the only recent type of the form that I am acquainted with, although, as it will be hereafter seen, this tubular form of the fibre is of frequent occurrence in the fossil sponges.

The results arising from the examination of the siliceous bodies of the chalk, greensand and oolitic formations, induced me to extend my researches to other siliceous masses; and with this view I obtained, through the kindness of Mr. Tennant, a considerable number of polished specimens of moss agates from Oberstein in Germany, from Sicily, and other localities.

I examined these specimens as opake objects by direct light concentrated on their surfaces by the application of a convex lens, and in many cases the results of the examination far exceeded my expectations of being able to detect the organic structures imbedded in them. Upon a minute and careful examination of numerous polished slabs of the moss agates of Oberstein, almost every specimen presented strong evidence of their spongeous origin. The structure and arrangement of the fibre of the sponge is rarely to be found in a state of perfect preservation throughout the whole of the mass, but usually presents the appearance of having suffered to a great extent by maceration and disruption of its component parts previous to its fossilization. Generally speaking, the fibres adhere together in confused and ropy masses, with here and there one or two in a somewhat better state of preservation, and occasionally, especially near the external sur-

* Published in the Transactions of the Microscopical Society, part the first, vol. 1, p. 32.

face of the original mass, small portions of the tissue are sometimes observed in so perfect a state as almost to deceive the observer into believing them to be fragments of recent sponges. In some parts of the mass, especially near that which is in the finest state of preservation, parts of the structure may generally be seen in all the intermediate stages between perfect preservation and nearly complete decomposition, where the organic tissues have resolved themselves into a shapeless mass, only to be recognised as formerly having belonged to the sponge by the aid of the surrounding, connected and less decomposed parts of the animal structure.

The siliceous matter in which these remains are imbedded usually presents a clear and frequently a crystalline aspect, while the remains of the organized matter is strongly tinted with colour: bright red, brown and ochreous yellow are the prevailing colours, but occasionally the fibre is milk white or bright green. Sometimes the interior of the tubular fibre only is filled with colouring matter, while the sides are of a semipellucid or milky white; in others the whole of the fibre is impregnated with it. The colouring matter is generally confined within the bounds of the animal tissue, leaving its surface smooth and uninterrupted; but occasionally the fibre is not only completely charged with it, but its surface is also slightly encrusted by it.

These are the usual characters presented by the greater portion of the moss agates of Oberstein and other parts of Germany.

It would be taxing the patience of the reader to too great an extent if I were to attempt to describe the whole of these siliceous bodies that I have subjected to examination; I shall therefore confine myself to a detailed description of a few of the most characteristic specimens, and especially to those which afford the strongest and most perfect evidence of their organic origin.

The first of these specimens is a moss agate, said to be from Sicily. The structure of the sponge tubuli is very obscure in the greater part of the mass, but at the margin of the specimen the tubes are in as perfect a state of preservation as if they were those of a recent sponge immersed in Canada balsam; in this state they are represented in Pl. I. fig. 1. anastomosing precisely in the same manner as those of the Mediterranean sponge, and where they have been divided at the surface of the specimen they are frequently observed to be hollow. No spicula are present, but it is evident that it was a true keratose sponge. The greater part of the specimen consists of innumerable bright red fibres of nearly an uniform diameter, ramifying in every direction, frequently terminating as if

broken, and presenting appearances of much confusion and disarrangement, as at *a*, *a*, fig. 2, and no remains of the structure surrounding them are perceptible. But in some few portions, and especially near the margin where the perfect sponge-tubes are found, we perceive each of these red fibres to be enveloped by the semipellucid and horny-looking substance of the sponge, as seen in the centre of Pl. I. fig. 2, thus proving that the *red* fibre is in reality the cast of the interior of the tubular sponge fibre; and if we compare them with the hollow spaces of the perfect tubes, we find them to be as nearly as possible of the same diameter.

In the portion of the agate represented by Pl. I. fig. 2, there are parts of the tissue seen at *b*, *b*, *b*, into which the red pigment does not appear to have entered, and when the fibre is in the most perfect state of preservation this is usually the condition in which it is found; and it is natural that such should be the case; for in the recent type of these sponges, *Spongia fistularis*, it is always found, that although the internal cavity is continuous throughout the whole of the fibrous structure, yet that it is universally closed at a short distance before it arrives at the natural termination of a fibre.

In another specimen, which is in my possession, of a moss agate from Oberstein, we have the spongeous structure in a different form. In the first specimen described the most striking feature is the bright red fibrous-looking casts of the interior of the sponge-tubes; while, in this, we have in the best preserved parts of the structure the walls of the tubes themselves impregnated with the red pigment and the interior of the tubes filled with pellucid silex; while in that portion which has suffered most by decomposition, there is a confused mass of bright red with obscure traces of fibrous structure, with here and there a fibre in a sufficiently good state of preservation to enable us to recognise the whole as the same substance as the more perfect structure, but so obscured by decomposition as to render it perfectly undistinguishable from inorganic and extraneous matter, if it were not for the better state of preservation of other parts of the sponge.

Another agate which I examined I found to be, literally speaking, a complete mass of sponge. The fibre of the centre of this specimen, for about one-third of its diameter, is of a bright red colour, the surrounding part is of an ochreous yellow, but the organized structure does not vary in any respect but in colour. There are the casts of a few small foraminated shells dispersed amid the spongeous tissue, and in a few irregular cavities which occur in it I observed that the silex was arranged in that peculiar stratified mode which stamps it as an agate. In the fourth agate examined, the sponge-tubes

were seen in a fine state of preservation in several parts of the specimen, and were very similar to the tubes described in the former instances, both in their dimensions and mode of arrangement. The substance of the tube is of an opake white, while the interior is filled with the bright red pigment before described. In this case also, as in the former ones, the fibrous casts of the interior of the tubes occupy a great part of the space within the agate, with an occasional intermixture of what is evidently a disorganized or semi-decomposed mass of the horny tubes.

The fifth specimen is also a keratose sponge, the tubes of which are very slight, and the points at which they anastomose are more distant from each other than in the former cases that have been described. The sides of the tubes are composed of the red pigment which usually does not extend beyond the boundary of the horny substance; but in some parts of this specimen it not only thus supplies the place of the horny matter, but a quantity of it has also been deposited around the tubes, greatly increasing in appearance their natural diameters, and indicating the strong elective attraction that has existed between it and the animal substance of the sponge: and this is rendered the more evident by this red pigment not being perceived in any other part of the siliceous mass beside that occupied by the sponge-tubes, either in a state of perfect preservation or of semi-decomposition; the whole of the spaces between these portions of animal matter being occupied with unstained and beautifully pellucid silex.

The fibres of all the specimens hitherto described are truly tubular, and in this respect strongly resemble in their structure the recent *Spongia fistularis*. In their arrangement of their fibres and their mode of anastomosing they appear very closely to resemble the sponges of commerce and many of the Australian keratose species.

Such are the prevailing characters of the sponge tissues to be found in the German and Sicilian moss agates. I have examined nearly 200 of these interesting bodies, and in the whole of them I have been enabled to discern spongeous tissue either in precisely similar states to those tissues that I have described at length, or in some modification of them; and it is only in very few cases indeed that a careful and patient examination of a specimen, however indistinct it might at first have appeared, has not been rewarded by finding in some part of it, not only the casts of the interior of the fibre, but portions of the fibre itself in a sufficiently perfect state to leave no doubt remaining upon my mind of the truth of its animal nature.

The green jaspers of India are also fruitful sources of

spongeous tissue; and generally speaking, the organic structure is in a better state of preservation than it is in the moss agates of Germany and Sicily. The green colouring matter in these siliceous mosses is found, with very few exceptions, to be confined within the boundaries of the sponge fibre, the surrounding siliceous matter consisting of minute pellucid radiating crystals, which have for their bases the sponge fibres, amid which they have been deposited. Upon taking some small thin pieces from various parts of a large mass of this mineral in the possession of Mr. Tennant, I found every fragment of it to abound with beautifully preserved ramifying sponge fibres; and upon examining numerous small rough specimens of this substance, some of which I obtained from the same gentleman, and others from a lapidary in Clerkenwell, I found the whole of them to abound, in a similar manner, with well-preserved fibres of various species of sponges. On a few of these small rough specimens a portion of the natural external surface remained; and upon examining this as an opake object with direct light and a microscopic power of 500 linear, I found some of them to be furnished with minute contorted tubuli very similar to those which I described in a former paper as occurring upon the surface of chalk flints *. Upon examining some very dark-coloured polished specimens of a green jasper which I obtained from Mr. Tennant, I found the spongeous structure in a more perfect state of preservation than in any of the specimens previously examined.

The fibres in this case are not disposed in the same manner as in the sponges of commerce, but are arranged in a series of thin plates, resembling very much in their appearance portions of macerated woody fibres of the leaves of some endogenous plants. This singular form of tissue I believe to be exceedingly rare among recent sponges, as I have met with it in but one species which came among the large collection of sponges received from my friend Rupert Kirk, Esq., of Sydney, who obtained them on the coast in that neighbourhood. On examining about seventy thin sections of green jasper which I obtained from a lapidary in Clerkenwell, and which were said to have been imported from India, I found the results equally satisfactory: every specimen afforded undeniable evidence of spongeous origin, and in the greater part of them the organic structure was in so perfect a state of preservation as readily to admit of their being recognised as distinct species. Among this series of specimens there were several slices which had evidently been cut from the same mass which pre-

* Transactions of Geological Society of London, New Series, vol. vi. p. 183, pl. xviii. fig. 2.

sented appearances of an exceedingly singular nature. The substance of the sponge in this instance appears to have suffered so much by decomposition as to prevent its being detected in its original fibrous form. It has, in fact, become a confused magma of disintegrated spongeous matter, only to be recognised as such by the frequent occurrence of similar decomposed material in other bodies of the like description. Amid these remains of the sponge there are an innumerable quantity of globular vesicles of nearly a uniform size: many of these are simple and transparent, and only to be recognised as organized tissue by the regularity of their size and form, and by having universally dispersed over their outer surfaces minute irregular particles of an opake black matter: but by far the greater number of them are furnished with a globular opake body of about one-third their own diameter, which usually occupies the vesicle, and which causes it, when in this perfect state, and when seen with a linear power of about 150, and represented by Pl. I. fig. 3, very strongly to resemble the separated ova of the frog when immersed in water. Along with these vesicular bodies, there are numerous small brown fibrous masses which resemble very small keratose sponges: the largest of these are about five or six times the diameter of the vesicles, and they are seen decreasing gradually in size until they may be traced to be identical with the nucleus contained within the vesicles, but in a higher stage of development, as represented at Pl. I. fig. 4. *a*, *b*, *c* and *d*. Upon carefully examining the other specimens of this series, I found in several of them similar vesicular bodies of a large size imbedded amid the fibrous tissue of the sponge. They were more sparingly dispersed through the tissue in the latter cases, but in every other respect they closely resembled those first described. These curious vesicles have evidently existed before the siliceous matter became solidified, as each of them has become a base from which a mass of acicular calcedonic crystals has radiated.

From the whole of the circumstances attending these interesting remains, their uniformity in size and shape, their gradual development into small masses of sponge-like tissue, and the great similarity that they bear to the ova of numerous species of British sponges, described by Dr. Grant in the valuable papers on these subjects published in the 'New Edinburgh Philosophical Journal' of 1827, little doubt remains on my own mind that they are the fossilized gemmules of the sponges which have given form to the siliceous masses in which they are imbedded. It is true they differ from the gemmules of the British sponges described by Dr. Grant, as the latter are oviform, while the former are

spherical; but this variation is of no moment, as we shall hereafter find that in other cases the fossilized gemmules are oviform like those of various species of British *Halichondria*; while in the recent sponge from Australia, which I have described in the 'Annals and Magazine of Natural History' for April 1841, the gemmules are precisely of the same form as those occurring in the green jasper described above. It is a singular circumstance that the mode of propagation of the sponge should be thus capable of demonstration from the fossil specimens, but the case which I have just described is by no means rare in its occurrence. In an agate which is said to have come from Oberstein, the gemmules are seen apparently in an immature state attached in considerable numbers to the fibre of the sponge; and in the two portions of this specimen, which is represented by figures 5 and 6, and which are drawn to the same scale, it is apparent from the variation in their size that they are in different stages of development. In another agate in my possession, which I believe to be from Oberstein, and in which the spongeous fibre is in a most perfect and beautiful state of preservation, the gemmules are seen sparingly scattered amid the tissue. Some of these have the usual form of round compact globules pellucid for a small space inwards from the circumferential line, but dense and opake thence to the centre; while others appear to have been partially developed without having been ejected from the parent body, as they present the appearance of well-defined globular sponges, whose diameters are three or four times that of the undeveloped gemmules, as represented by Pl. I. fig. 7. If this idea of their development *in situ* be correct, it will perhaps account for the frequent occurrence of the small detached patches of minute sponge-fibre that are so often found imbedded amid the well-developed and large-sized tissue of the sponge which is especially characteristic of the various masses alluded to.

In a fourth agate, which probably came from the same place as the last, the fibre of the sponge has suffered so much by decomposition as to leave but few pieces of it in so fine a state of preservation as that represented by Pl. II. fig. 1. There are none of the gemmules in this specimen which are adhering to the fibres; but although not seen in actual attachment, they are dispersed in great numbers throughout the whole of the mass, and are seen in various stages of development, as represented in Pl. II. fig. 2. Among them are interspersed vast numbers of small pellucid yellow globules, which bear a striking resemblance to similar minute granular bodies that are observed in great abundance imbedded in the gelatinous or fleshy sheath that is found surrounding the fibres of

the sponges of commerce, and which are probably incipient gemmules. In a fifth specimen of agate that I procured from Mr. Tennant they assume a very singular appearance. Some of the gemmules are in a very perfect and beautiful state of preservation, and in this condition are separated from each other; while others are observed, apparently, in various stages of decomposition, presenting no definite outline or distinct or regularly marked surface, but assuming the appearance of having been resolved into gelatinous masses which have run together into moniliform strings, in a manner very similar to the mode of arrangement assumed by the discs of the blood when vitality has ceased to exert its repellent influence upon them, as seen in Pl. II. fig. 3.

Numerous other cases might be cited if it were necessary to prove the spongeous nature of these interesting remains, and the frequency of their occurrence in masses of agate; but I shall content myself with selecting but one more; and this I have chosen, not only because it is one of the most perfect and illustrative of the spongeous nature of these remains, but also from its occurrence in a class of siliceous bodies which we have not hitherto noticed. The specimen to which I allude occurs in a siliceous mass from the island of Antigua, and is in the possession of Dr. Robert Brown, who has favoured me with the loan of it. The agate in which this beautiful sponge occurs is nearly four inches square by about two inches thick, and is part of an originally much larger mass. Its natural surfaces do not afford any indication of its spongeous origin when examined by a lens of an inch focus, and the cut or fractured surfaces when examined in the same manner would rather lead us to believe it to be a coral than a sponge, from the whiteness of the tissue and the regularity of the arrangement of the large excurrent canals. There are also plates of spongeous tissue projected from the parietes of these canals towards their centres, which cause them strongly to resemble the sections of the polyp cells of corals; but this resemblance to the coral tribe ceases when a thin slice is examined as a transparent object with a power of 150 linear. The whole is then seen to be composed of the usual anastomosing fibres which are so characteristic of the keratose tribe of sponges. Even in the best preserved parts of the specimen the fibres appear to have undergone decomposition sufficient to render the characters of their surface somewhat indistinct, but not to such an extent as to interfere with their mode of arrangement. A section at right angles to the axis of one of the most distinct and best preserved of the excurrent canals is represented by Pl. II. fig. 4. There are six large plates of reticulated

spongeous tissue projecting from the inner surface towards the centre of the canal for about one-third of its diameter, and to the sides of these there are oviform gemmules attached in such numbers as to assume in some parts very much the aspect of a cluster of grapes, and against one portion of the side of the canal they are grouped in a similar manner. The mode of their attachment to the plates of tissue cannot be observed, in consequence, not only of their position, but also from their crowded state; but at the terminal edge of one of the plates which reaches nearly to the centre of the canal, there is seen one of the largest oviform gemmules that is within the field of vision, from beneath which a single fibre of the sponge is seen to emerge and pass towards the centre of the canal, near which it terminates abruptly as if by fracture. There is a gentle curve near the middle of this fibre, in the hollow of which a gemmule is seated that is nearly equal in size to the one adjoining; so that the position and distinct attachment to the fibre of the sponge of this oviform body removes the possibility of a doubt of their being the true ova or gemmules of the sponge. In the two gemmules last described, the nucleus is distinct and well-defined, and is of a size equal to about a third of the smallest diameter of the gemmule; in some of the others it occupies nearly the whole of their interior, while in the greater number of them it is either very indistinct or not at all apparent. In all these respects the gemmules agree perfectly with those before described, as occurring in the green jaspers as well as in the other agatized bodies referred to.

The ova of birds, of fishes, and of reptiles, are always provided by nature with either a bony, horny, or tough membranous covering to protect them from the numerous accidents to which they are of necessity exposed until they arrive at maturity. It is therefore but natural to expect that the ova of the sponge tribe should be furnished with a means of preservation of a similar description, and thus it is that we find them the last and only remains of the sponge from which they date their origin. The presence of the gemmules in the agates and green jaspers that have been already described, is perhaps the strongest evidence of their organic origin that has been adduced, as in most of the cases cited the organic structure of the fibres has been in such a state of decomposition as to afford by no means the amount of evidence of their animal nature, that they are capable of producing, when examined in a more perfect state than that which has hitherto been described.

[To be continued.]