nodules; and when sections are made of these, they are found to show under the microscope structures and spicula allied to those of *Alcyonaria*. Slices of the *common* nodules show similar spicula, and occasionally reticular structure. When casts in plaster are made from *Alcyonium digitatum*, and coloured to resemble the nodules, the similarity in general form and structure of surface is very striking. The phosphate was probably segregated by the animal matter from its solution in water charged with carbonic acid, which is a known solvent of the phosphate; an analysis of the matrix has proved that phosphate of lime is appreciably present in it. The author doubted the derivation of the nodules from the denudation of the subjacent Gault, and exhibited a collection of these to show that they were distinguished by more stunted growth.

The deposit was on the whole considered to represent the thin band with similar fossils at the base of the Chloritic Marl, as seen in the west of England, in which district it is underlain by the true arenaceous Greensand. The absence of the true Greensand was attributed to the intervention of the old palæozoic axis of the London area; and it was finally suggested that a similar axis might stretch from Leicestershire to Harwich, causing the change in character of the Lower Cretaceous beds between Cambridgeshire and Norfolk.

3. *Some Observations on the UPPER GREENSAND FORMATION of CAMBRIDGE.* By W. JOHNSON SOLLAS, Esq., Scholar of St. John's College, Cambridge; Associate of the Royal School of Mines, London.

(Communicated by the Rev. T. G. Bonney, M.A., F.G.S.)

[Abridged.]

THE so-called Upper Greensand formation around Cambridge consists of a Chalk-marl, with various inclusions disseminated throughout it. These inclusions are separated for manufacturing-purposes from the Chalk-marl by levigation, and sorted by a process of sifting into (i) larger bodies, which remain in the sieve, and (ii) smaller ones, which pass through it. The larger bodies consist almost entirely of the so-called "Coprolites;" and the smaller ones form the so-called "Greensand," which gives its name to the formation.

The Coprolites.—In all cases the coprolites are the result of the fossilization of organic matter or of the immediate products of its decomposition. The connexion between animal matter and the formation of coprolite is one of the most obvious facts of the whole subject. The bones of reptiles and fishes are incrustated with coprolite precisely on those parts where cartilage was most abundant. The palates of fish such as *Pycnodus* are not incrustated on their free surfaces; but their attached surfaces, once covered with cartilaginous tissue, are now quite imbedded in coprolite. In Crustacea such as *Palæocorystes* the under surface of the body, where animal matter could easily escape, is often one mass of coprolite; while the back of the carapace, which was not covered with animal

matter, is generally free from incrustation. Many other examples might be cited, all pointing to the intimate connexion between the presence of animal matter and phosphatic deposition. The basis of animal matter was derived from various sources; the fossil remains of Vertebrata, Crustacea, Echinodermata, Mollusca, and so forth are coprolites the origin of which is clearly evident. But these constitute only a fraction of the whole; of the rest, the nature of which has hitherto been unknown, the majority are fossil Sponges, and of the minority remaining some few are formed from phosphatized animal matter decomposed so far as to have lost all traces of its original structure before mineralization. In some cases this animal matter may have been derived from small fish, since bones and scales of fish are found in some kinds of coprolites.

General similarity of some Coprolites to Sponge-forms.—Cylindrical and cyathiform coprolites are abundant, consisting of a central core of Chalk-marl surrounded by an outer annular portion of coprolitic material, which is still impregnated with animal matter. These two parts together mark out the former existence of a hollow cylinder of animal matter, such as is exhibited in various recent and fossil sponges, and, taken in conjunction with other characters, seem to indicate an affinity to the Spongidae. If this be so, the chalk core fills up what was once the cloaca of the sponge, and the phosphatic material replaces its animal matter. Minute pits upon the surface indicate the oscula. More important facts regarding this and other forms will form the subject of a future communication. In the Upper Chalk silicified sponges form flints, in the Upper Gault phosphatized sponges form coprolites; thus the coprolites might almost be termed the flints of the Gault.

The Greensand consists of (1) calcareous, (2) siliceous, (3) glauconite and coprolitic granules.

(1) *Calcareous grains* comprise sponge-spicules, spines and plates of Echinoderms, minute shells, shell-fragments and prisms, Polyzoa, bivalve Entomostraca, microscopic corals, Foraminifera, and calcareous concretions.

Calcareous concretions.—Rather abundant, subspherical granules varying in size, generally from $\frac{1}{15}$ to $\frac{1}{30}$ of an inch diameter, looking like rounded grains of milky-white quartz or spinose Foraminifera. Sections reveal a crystalline structure radiating from the centre, crossed by concentric lines of growth. Centre with a nucleus or not.

Foraminifera.—*Trochammina* and *Lituola* very abundant; *Lagena*, entosolenian and ectosolenian forms; *Nodosaria*, *Dentalina*; *Orthocerrina*, very arenaceous forms; *Frondicularia*, *Vaginulina*, *Flabellina*, *Textularia*, and *Bulimina*, very arenaceous forms, of large size; *Cuneolina*, *Rotalia*, and *Globigerina*. Numerous species of *Lagena* occur abundantly, especially entosolenian forms: except *L. apiculata*, recorded by Reuss in the Gault, this genus has not hitherto been found below the Maestricht Chalk.

Entomostraca.—*Cythereis quadrilatera*, *C. ciliata*, *C. triplicata*;

Bairdia subdeltoidea; *Cytherella truncata*; *Cythere punctatula*, *C. umbonata*, and others. *C. umbonata* has not been found before below the Chalk-marl.

(2) *Siliceous sand*.—Small grains of coloured quartz, obsidian, grit, and other rocks form a small proportion of the Greensand. Foraminifera of arenaceous habit often imbed these grains in their tests.

(3) *Glaucinite and Phosphate Grains*.—The phosphate grains consist of coprolitic *débris*, coprolitic casts of Foraminifera, and small ovuloid granules and cylinders of unknown derivation.

The glauconite grains are the casts of Foraminifera, possibly also of other minute shells. The larger casts, about $\frac{1}{40}$ " to $\frac{1}{60}$ " in diameter and less, are marked into projecting lobes by deep sulcations, generally lined at the bottom with white calcareous matter, which serves to mark out the limits of each lobe. These forms are derived from *Textularia*, *Lituola*, and *Bulimina*; in size they correspond very closely with such a derivation, just passing through the meshes of a sieve which retain almost all the numerous *Buliminae* mingled with them. Each lobation of the cast corresponds to the interior of a chamber of the Foraminifer; and each white calcareous line between the lobes is the edge of the septum which once separated adjoining chambers, and now, in some cases, extends inwards between their casts. This is shown by sections made in various directions through the green grains. When one of these sections of glauconite is viewed with polarized light, distinct colours are obtained; with parallel prisms, dark green; and a bright, lighter-coloured green, with crossed prisms. Sometimes *Buliminae* are met with having part of their shell worn away, revealing a green cast within. Besides the above, other forms are found as casts in the sand—*Orthocerina*, numerous elongated triangular pyramids (rarely constricted into definite lobes), *Rotalia*, one or two minute *Nodosariae*, small fusiform casts from *Lagena*, and distinct *Globigerina*-casts. Minute globules $\frac{1}{1000}$ " to $\frac{1}{2000}$ " in diameter, occur plentifully the smaller ones are probably detached spheres from *Globigerina*-casts, and the larger ones casts of chambers broken off from other Foraminifera, as *Bulimina*; frequently glauconite may be seen through the worn-away shell of such chambers. *Globigerina*, *Rotalina*, and various pseud-arenaceous forms sometimes show green casts in their interior. From the resemblance of most of the green grains to the Foraminifera found with them, from their rough parallelism in size, from the appearance of many of the grains when sections are made of them, and from the occurrence of glauconite-casts in the interior of the original Foraminifera, we must attribute to the green grains a Foraminiferal origin. That this has not been determined by previous observers is partly due to the use of acid, after Ehrenberg's directions, in preparing the sand; this of course would obliterate the calcareous lines which distinguish the lobations. The silica and various silicates mingled with the glauconite grains must have thrown the analysis of these grains hopelessly wrong.

In conclusion, I have great pleasure in thanking the Rev. Mr. Bonney, of St. John's College, for the kindness he has shown me in many ways throughout this investigation.

DISCUSSION.

Prof. PHILLIPS was glad that his casual remark had produced such satisfactory results as the papers he had heard. It was satisfactory to find that the bulk of the phosphatic nodules exhibited such marked traces of an organic origin. Though he had to some extent been prepared for this, it appeared that the view might be extended much further than would at first sight have been anticipated. He drew an analogy between the preservation of the forms of sponges in their silicified fossils with that of the soft organic bodies in the Greensand by phosphatic matter. In each case the surrounding water contributed a large amount of either flint or phosphate of lime, which was segregated and accumulated round certain centres or nuclei of organic bodies.

Prof. RAMSAY inquired from what sources the abundance of phosphatic matter requisite for the production of these fossils could have been derived. In such thin strata, which seemed to indicate a transition from a land to a marine surface, it was a matter of great difficulty to his mind to account for so great an abundance of phosphatic matter.

Mr. GODWIN-AUSTEN remarked that phosphoric acid was largely present in sea-water, and instanced the present seas, where, as on the Newfoundland banks, fish existed in enormous quantities, and no doubt also phosphatic matter. The Cambridge beds, though so rich, were by no means unique of their kind. He referred to a paper communicated some years ago to the Society by Mr. Payne, as affording many interesting particulars with regard to such beds. He considered that much of the phosphate attaching to decaying animal matter might have been derived from comminuted excrementitious deposits floating in the water.

The Rev. T. G. BONNEY remembered a fact quoted by the late Dr. Mantell as to the large quantities of dead Mollusca which had been observed floating down some of the American rivers, and which had been regarded as a plentiful source of phosphatic matter. Small fishes might also have furnished a considerable quantity, and their value as manure was recognized at the present day. With regard to the nodules being Aleyonaria or sponges, he observed that what spicules he had seen appeared more like those of sponges. He agreed with Mr. SOLLAS as to the foraminiferal origin of many of the green grains. He did not agree with Mr. FISHER in attributing all the nodules to the bed in which they were found, but thought that a considerable portion might be referred to the upper part of the Gault. In proof of the washing the Gault near Cambridge had undergone, he mentioned the occurrence there of a number of boulders of rocks quite foreign to the district.

Mr. J. F. WALKER thought that most of the fossils of the phosphatic band at the base of the Chalk-marl were derived from the Gault, whilst the bed differed from Chalk only by green grains becoming gradually more abundant. The fossils were generally much waterworn; the characteristic fossils of the Warminster Greensand were absent; and the most abundant fossils were all of Gault species. It seemed that wherever these accumulations of phosphatic matter occurred, denudation had taken place, and that they were the residuary heavy materials of a large thickness of rock. This might also be observed in the Upware and Potton beds.

Mr. WHITAKER observed that the Upper Greensand thinned out as much to the south as to the north of London. He inquired as to the alleged abundance of phosphate of lime in the upper part of the Gault. He doubted whether the thin band at Cambridge could represent the great thickness of Upper Greensand which was to be found in some other districts. He regarded it rather as a gradual passage into chalk, though the line of demarcation was evident on the Gault. Though agreeing with Mr. Walker as to some of the fossils having been derived from the Gault, he could not regard them all as having come from that source.

Mr. MEYER thought that the Greensand had always been absent in the Cambridge district, and mentioned the occurrence of a bed of much the same character as that in question at Niton in the Isle of Wight.

Mr. FORBES pointed out that the amount of phosphatic matter in fishes was so small that it was difficult to assign such an abundance as that described to this source. In limestones all but entirely composed of shells, he could find only from $\frac{1}{2}$ to 1 per cent. of phosphate of lime. Even with true coprolites, he thought that they had become richer in phosphate since their deposition; but whence this phosphate was derived he would not pretend to say. He thought this question of derivation still open.

Prof. MORRIS mentioned the occurrence of similar deposits near Wissant, on the coast of France, and near Calne, in Wiltshire. He called attention to the extremely quiet nature of the sea in which the phosphatic bed had been deposited, and observed on the existence in recent times on certain sea-shores of ooze containing a large amount of phosphatic matter.

Mr. FISHER, in reply, stated that he had in his paper but slightly touched on the sources of derivation of the phosphate of lime; but as to the possibility of that substance being localized and derived in large quantity from fish, he pointed out that the principal manure of modern times, guano, was derived from this source. He alluded to the possibility of some process of dialysis having contributed to the segregation of the phosphate. He disputed the identity of the nodules in the Gault and in the chloritic marl of Cambridge. As to the character of the fossils, he regarded it as the same as that to be found in a thin band at the base of the Chalk in parts of Hants and Dorset.

Mr. SOLLAS had examined sections of the fossils from the Cambridge beds under the microscope, but had failed to find the canals or tuberculated spicules characteristic of *Aleyonaria*. He had, however, in the sand found numerous indisputable sponge-spicules. He had, moreover, found in sections of the coprolites spicules such as were regarded by Dr. Bowerbank as characteristic of sponges. He hoped, however, to recur to the subject. Both Mr. Fisher and himself concurred in removing these nodules from the category of concretions, and placing them under the head of organic fossils. The transported blocks in the beds bear evidence of glacial action, and, he considered, had been brought from Scotland or Scandinavia. The cold sea then existing at the base of the Scandinavian chain of mountains flowed southward over the bottom of the ocean, carrying with it mineral matter in solution, particularly phosphates; so that in this way, he thought, some portion of the phosphatic matter was derived from the decomposition of the volcanic rocks north of the Lammermuirs, which were rich in this substance, and of which rocks he had found fragments near Cambridge. He considered that, under certain circumstances, the phosphatic matter present in water would combine with animal matter, and hoped at some future time to offer some remarks on this subject to the Society.

JUNE 5, 1872.

Isaac Shone, Esq., of Bersham Hall, near Wrexham, Denbighshire, was elected a Fellow, and Prof. J. D. Whitney, of Cambridge, U.S., a Foreign Correspondent of the Society.

The following communications were read:—

1. *Notes on SAND-PITS, MUD-DISCHARGES, and BRINE-PITS met with during the YARKAND EXPEDITION of 1870.* By GEORGE HENDERSON, M.D., F.L.S., Surgeon H.M. Bengal Medical Service, and lately Medical Officer to the Yarkand Expedition of 1870.

(Communicated by R. Etheridge, Esq.)

WHILST accompanying Mr. T. D. Forsyth to Yarkand in the summer of 1870, we came upon extensive tracts of ground indented with very remarkable circular pits, which I was very much puzzled to account for.

Where first seen, they appeared like the holes made in washing for gold, as practised both in Tibet and Yarkand; but there was none of the excavated material to be seen round their margins, and they were a hundred miles or more from any human habitation; besides, they were much too regular in size and shape to be thus accounted for.

I noted at the time every circumstance which I thought likely to give a clue to the manner of their formation; but, from the rapidity