42. *The GREENSAND BED at the BASE of the THANET SAND.* By
MISS MARGARET I. GARDINER, Bathurst Student, Newnham
College, Cambridge. (Read June 20, 1888.)

(Communicated by J. J. H. TEALL, Esq., M.A., F.G.S.)

THIS bed may be seen at various points from Pegwell Bay in the east to Chislehurst in the west of Kent, and there is a bed at Sudbury, in the N.W. corner of Suffolk, which Mr. Whitaker considers to be the same*. At Lewisham and Croydon, to the west of Chislehurst, it is missing, and the light buff micaceous sand which usually succeeds it in West Kent rests directly on the flint bed above the chalk; so that, unless either the 9 inches of greensand and flint or the 2 feet of grey sand last seen in 1830 at Epsom by Prof. Prestwich are the same, the succeeding beds of the Thanet Sand overlap it westwards.

Specimens have been obtained from Pegwell Bay, Chislet near Herne Bay, Upnor, Chislehurst, and Sudbury. Leaving for the present the Sudbury sand out of consideration, this basement bed is a very fine sand formed of about equal quantities of dark and light grains mixed with more or less clayey matter. Its appearance in a section varies considerably with the weather, for it is the dark greenish grey of the darker grains which gives the colour when it is wet; but when it is dry the clayey matter becomes a white powder, and is a much more conspicuous constituent. A microscopic inspection shows the sand to consist of quartz, flint, glauconite, and small quantities of felspar and various rarer minerals, with a few casts of microscopic organisms.

Quartz.—The quartz is in not much rounded grains of average largest dimension about .1 millim. One of the striking points about the sand is the small proportion of quartz-grains, namely, only about 45 per cent.

Glauconite.—The glauconite-grains are small as compared with those of most greensands. The majority are of rounded outline, and consist of an aggregation of smaller grains, often wedge-shaped in form and fitted together in a convolute manner. The cracks between the parts of the grain are marked by a yellow line, probably of iron-oxide. This kind of aggregate seems to be the commonest form of glauconite-grain, and occurs in those of the Cambridge Greensand, Lower Greensand (Folkestone), Upper Greensand (Highclere), and the basement bed of the Woolwich Sands. Other green grains are subangular. Some of these are only pieces of the round grains, but others are probably coated grains of flint or quartz, since some may be seen to give a distinct quartz-reaction. When mounted in balsam the glauconite is opaque except just at the edge, but in water or glycerine by

* Geol. Surv. Mem. to Sheet 47.

transmitted light, and always by reflected light, it is a bright yellow green. That of some other sands, *e. g.* the Cambridge Greensand and the basement Woolwich beds, is a very blue green. Between crossed nicols it gives either no reaction or a speckled look, somewhat like that of flint. The glauconite-percentage is only 15.

Flint.—On first looking at a slide of this sand one is struck by the large number of very sharply angular chips. These may be roughly divided into two sets, the one transparent, the other almost or entirely opaque. The transparent ones have a rough pitted surface, which gives them a slightly greyish tint, and are often marked by small black dots, which, when present in any number, give the grains a darker colour. Between crossed nicols they have a minutely tessellated appearance, the lighter parts being of a bluish neutral tint. Their close resemblance to chips obtained by crushing a flint seemed to leave little doubt as to their nature; but, since the glauconite gives a somewhat similar reaction, it seemed possible that at least some of the more rounded grains, or those which gave a less distinct reaction, might be weathered glauconite. As a test, glauconite grains were bleached by boiling in hydrochloric acid, and it was found that these could be distinguished from the flint by their different surface, clearer colour, and less distinct outline. The Upper Greensand (Highclere) was then examined for comparison. It is a very similar sand of quartz and glauconite. Though the glauconite-grains are in all respects like those of the Thanet Sand, yet there are no grains which could be mistaken for flint. There seems no reason why the glauconite-grains in the one should be supposed to have lost their colour by weathering when they have not done so in the other. Finally the sand was placed in a borotungstate solution of sp. gr. just below that of flint; although a few green grains fell through, all those floated out, with the exception of a very few grains of both quartz and flint which had probably adhered to the side of the funnel, were green. Therefore, unless the glauconite increased in sp. gr. by weathering, these grey grains cannot be glauconite. A consideration of this evidence seems to leave no doubt that these lighter grey grains are flint, although they form the abnormally large proportion of 20 per cent.

The more opaque grains are in general form like the clear ones. In both, forms which resemble microscopic spear- and arrow-heads are not uncommon. There is a more or less distinct transition from the clear to the opaque, and some are opaque in parts and clear in others. By reflected light many show the same greyish colour as the clear grains, though many are almost black. In fact, by reflected light one often cannot tell whether a particular grain is transparent or opaque, though both are easily distinguished from the quartz- or the green glauconite-grains. Crushed fragments of the weathered white coating of a flint are very like some of the more opaque and transitional forms by transmitted light, though these differ by being white in reflected light. The slightly weathered surface of a black flint is such a mere film that it has not been found

possible to get pieces of it to compare; but some of these grains look by reflected light very like small, black flint pebbles, and the double thickness of weathered coating even, though thin, might be sufficient to make them opaque. In the boro-tungstate solution these opaque grains fall with the clear ones. Altogether there seems to be no reason for considering these grains to be glauconite, as their comparative opacity and the faint reaction which they sometimes give in parts between crossed nicols at first inclines one to do. The evidence there is seems to be in favour of the supposition, suggested by their form, that these grains are also flint. Counting these in with the others, the flint-percentage rises to 40. This and the other percentages have been obtained by counting between 3000 and 4000 grains. The flint-grains are of about the same size as the quartz-grains, *i. e.* about 1 millim. in their longest dimension.

It is these opaque grains quite as much as the glauconite which give the dark colour to the sand; for when the clay is washed out, what remains is dark grey, quite black when wet; but when the clay is washed out of the Upper Greensand, which is a sand very like this without the flint, the residue is of a light green colour.

Besides these flint-grains, larger ones which might almost be called small pebbles, about $\frac{1}{16}$ inch in diameter, are often found, and at Pegwell Bay much larger flints, some slightly rounded like those just above the chalk, and others which are regular pebbles. Six were picked out of a piece of cliff about 2 feet square, but in most parts they were not quite so numerous.

Twinned Felspar occurs in no great quantity. What there is is very generally twinned in two directions.

Magnetite and Spinel.—Amongst the grains which come down in a boro-tungstate solution of sp. gr. 2·9 black opaque grains are the commonest. Amongst these some are very perfect octahedra. Only some seem to be magnetic, so that probably both magnetite and a dark spinel are present.

Zircon also forms a large proportion of the heavier minerals. It occurs in very perfect crystals and in grains. The crystals differ considerably in size and form. Two from amongst the larger and smaller respectively measured ·116 millim. $\times$ ·036 millim. and ·06 millim. $\times$ ·02 millim. Often only the (100) and (101) planes are developed, but sometimes also the (110) and (111) and other pyramid planes. Very frequently one pair of the (101) planes is developed at the expense of the other, so that the crystal has a truncated appearance. There are often needle-like inclusions parallel to some of the pyramid faces.

Garnet (?).—In about the same quantity is present a mineral of which only broken fragments of fairly large size have been seen. It is very clear, colourless, highly refracting and isotropic. The fragments are often very sharply broken, and sometimes the fracture has a conchoidal look. Inclusions of black and green grains are not uncommon.

Rutile is not present in such quantity as the minerals already

described, though there is always some in any slide of the heavier minerals separated from this sand. It is in long narrow prisms and grains.

Tourmaline is present in about the same quantity. It is dark brown, purplish grey or very light and almost colourless. The light variety is in small and very perfect crystals, often as broad as they are long, so that they have the outline of a hexagon. They are terminated at both ends by the rhombohedron-planes, but the darker varieties are generally broken, or if not, the rhombohedral planes are only at one end, and the basal plane is developed at the other.

Anatase has been looked for, but not found.

The description so far applies to specimens from all the places mentioned except Sudbury, that is to say, since these places are distributed along the whole length of the southern outcrop, it may be taken as a general description of the basement sand of the Thanet Sands in the South of England from a mineralogical point of view. The following minerals occur in very small quantities, and so are not in any way characteristic.

Garnet.—A few minute colourless dodecahedra have been noticed. One measured $\cdot 02$ millim. from one dodecahedron-face to the parallel one. One has grown round a smaller red crystal of the same form—a fact which seems to point to their being garnets.

Actinolite.—A few fragments of a fibrous-looking green mineral strongly pleochroic, or yellow-green, with vibrations parallel to the length, and blue-green with those in the opposite direction are probably actinolite.

Epidote.—One somewhat rounded crystal of the outline of an oblique parallelogram with the corners rounded off, strongly pleochroic and with very distinct cleavages, has been referred for me by Mr. Davies to this mineral. Judging by the colour and pleochroism other grains may be of the same mineral.

Chalcedony.—There are a few grains of a mineral polarizing in grey and having a spherulitic structure. Such grains are common in the residue of chalk dissolved in hydrochloric acid.

Organic Remains.—A few microscopic organisms have been met with, and are sufficiently numerous to render it probable that with careful searching many genera might be found. The commonest are siliceous, spherical bodies with a pitted surface, with a more or less distinct dark centre, apparently not casts. These may be either Radiolarians or Diatoms. Casts of Foraminifera, probably of the genera *Planorbolina* and *Textularia* in a clear, colourless mineral, perhaps chalcedony, have been noticed.

The Greensand bed at Sudbury.—This bed has apparently been classified with the Thanet Sand on account of its position and colour. The great point of difference from the southern greensand already described is in the much larger glauconite-percentage, which gives the bed a greener, less grey colour. Glauconite constitutes about 75 per cent. of the grains, and the proportion by bulk is still greater, since the glauconite grains are larger and the other grains smaller

than those of the southern bed. Under these circumstances it is difficult to compare the flint-percentage. The flint forms about 10 per cent. of the quartz and flint grains, leaving the glauconite out of consideration. This, though much lower than in the south, is still high. The quantity of sand other than glauconite in the specimen brought away was so small that it did not seem worth while to try to make a separation; but in slides of the sand left when the glauconite was washed off zircon, rutile, tourmaline, black mica, and fragments of the isotropic mineral described as garnet have been found. The points of resemblance to the southern basement-bed of the Thanet Sand are the facts that both are glauconitic, and contain a larger proportion of flint than is common, as well as fragments of a colourless garnet, which do not seem to be of such universal distribution as the other heavy minerals common to both. The basement Woolwich bed, though almost as largely glauconitic where it rests on the chalk in Hampshire, differs in several respects. Its glauconite is of a blue and not a yellow green; and though search has been made, no flint grains have been found.

The statement has been made in the Survey Memoirs that there seems to be no proof of unconformity between the Chalk and the Tertiaries. Prof. Prestwich, in his new volume, assumes such an unconformity, since he says, "as the area of the Chalk-sea at the close of the Cretaceous period gradually became more and more restricted during emergence, so the early Eocene strata during the first period of the following submergence were of very limited extent"*. Although a small flint-percentage might be due to an unconformity at a distance, so large a percentage could hardly have occurred in a sand formed far from the source of the flint; because the further the flint was carried, the greater would be the chance that, when deposited, it would be mixed with sand from other coasts. If such a sand could only be formed close to a chalk-shore, its existence at the base of the Tertiaries forms an additional piece of evidence in favour of the gradual extension of the early Tertiary sea described by Prof. Prestwich.

One at once wonders how so large a flint-percentage could have been formed in early Tertiary times, whilst the sand now being formed along a very similarly situated shore contains little or no flint. The difference may, perhaps, be due to a difference in the nature of the coast. Our coast consists of chalk-cliffs with the two long breaks of the Tertiary and the Wealden sands and clays. Is it not probable that currents drift the debris of these coasts as well as the material brought down by the Thames to mix with the debris of the chalk, and so *bring down* the flint percentage? If the early Thanet-sea stretched from the borders of Belgium as far north as Sudbury it would almost certainly have had something like 200 miles of unbroken chalk-cliff along its western shore, for the Tertiaries were not there, and even Prof. Prestwich, who seems to date the Wealden and Boulonnais anticlinal earlier than any one

* 'Geology: Chemical, Physical, and Stratigraphical,' vol. ii. p. 337.

else, does not give any reason for thinking that the chalk was quite cut through in the middle of the Wealden area before the deposition of the Tertiary beds. If there were no strong currents to bring material from the other coasts, such a shore would be just the place for the accumulation of sand largely consisting of flint. It is true that the succeeding beds have a flint-percentage of about 5, and cannot have been formed in a sea with very different shores; but it is possible that they are really contemporaneous beds formed further out to sea, which crept westwards after the flint-sand, the flint-sand always being formed against the cliffs.

DISCUSSION.

Dr. HINDE considered the paper important as showing the great amount of minute particles of flint present in these sands. It was a matter for regret that the Authoress could not be present when the paper was read.