ON THE DIVISIONS OF THE GLACIAL BEDS IN FILEY BAY.

BY G. W. LAMPLUGH, F.G.S.

UPON examination, the interesting, but hitherto neglected, drifts which fill the old preglacial hollow between Filey and Speeton are found to comprise in their sections a fuller series than is elsewhere to be seen in East Yorkshire, instead of all being included, as was supposed by Messrs. Wood and Rome, in but one division of their glacial series, that to which they have given the name of "Purple Clay without Chalk." *

So long ago as 1868, Professor Phillips,† in a short paper on the Hessle drift, pointed out that it was probable there were really two, or even three, boulder clays north of Flambro'; and, in a more recent paper, Mr. S. V. Wood‡ remarks that he and his colleague, the Rev. J. L. Rome, subsequent to the publication of their joint paper, traced the Hessle clay to the borders of Durham, though this does not seem to refer to the coast section.

So far from these drifts, then, being without division, we shall see that they may be clearly separated into even more than the three clays suggested by Professor Phillips, the divisions thus obtained being clearly the northern representatives of the clays seen in Holderness.

It is not, indeed, strictly necessary to suppose that each of the dividing lines which can be traced in these drifts marks a long "interglacial period." Whether they do or not is a matter of theory; but they are worthy of attention, even if looked upon simply as forming good lines of division, in the same way that the adjacent Neocomian clays of Speeton have been divided into numerous well-marked zones.

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* Quart. Jour. Geol. Soc., Vol. xxiv., p. 147.   † *Ibid.*, Vol. xxiv., p. 250.

‡ Geol. Mag., Jan. 1878, p. 17.

Nevertheless, there is evidence which convinces me that long and wide-spread breaks have occurred in the forces which brought together these clays.

At the base of the drift at Speeton is a band of very fine earthy chalk-rubble, resembling rain-wash. This bed is seen on both sides of the gully known as Speeton Gap, and may be traced from the Chalk Escarpment to the point where the Secondary (Neocomian and Kimmeridge) clays sink to the sea-level in New Closes Cliff, a distance of about three-quarters of a mile; and in an interesting exposure on the beach near Reighton Gap, nearly a mile further north, which I recently had an opportunity to examine, it still held its place between the drift and the Upper Kimmeridge Shale, which here formed the underlying bed.

At Speeton Gap this chalky rubble has a thickness of about ten feet; but in the exposure on the beach at Reighton it was much thinner, and probably dies out a little further to the north.

This bed may be of the same age as an exactly similar rubble which is seen on most of the preglacial chalk valley-slopes south of Flambro', and which holds a like position between the drifts and the underlying secondary strata.

Closely associated with this chalky rubble at Speeton is the Sand-bed containing a few species of shore-shells, to which Professor Phillips first drew attention,* and which was believed by him to belong to the drift series.

I have lately seen, however, that it is distinctly older than any boulder clay in Filey Bay; and as a representative of the oldest Yorkshire clay will presently be shown to occur here, it follows that it is older than any Yorkshire glacial deposit.

This shell-bed is first seen in the cliff a few hundred yards

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* "Geology of Yorkshire," 3rd ed., p. 101.

north of Speeton Gap. It is here that it was observed by Professor Phillips, and at this point it is 105 feet above high-water mark, but appears to sink rapidly over the steep denuded slope of the Secondary clays, as I have found traces of it considerably lower in New Closes Cliff, and again along the cliff foot as far as the ravine known as The Gill.

But as this interesting deposit has no direct bearing on the division of the drift, it will be unnecessary on this occasion to enter into further details respecting it.

In the exposure already mentioned, which I saw on the beach opposite to the village of Reighton, and which was afterwards visited by Mr. Dakyns and myself, the following sequence was observable, the beds apparently dipping towards the cliff, commencing with the lowest beds, those nearest low water :—

1. Highly contorted Upper Kimmeridge Shale.
2. Thin band of black silty mud, with broken fossils, being a re-arranged form of the underlying clay.
3. Band of fine Chalk rubble, with a streak of sand.
4. Brown Boulder Clay, with many stones—no shells.
5. Bluish Boulder Clay, with Shells, and with streaks of clean clay containing many Shells, mostly crushed.

NOTE.—These Shells had a facies totally different from that of the previously mentioned Shell-bed.

6. Patches, here and there, of a clean brown clay (without stones).
7. Greenish-purple Clay, with a few Shell fragments.

The exposure in which this series was seen was about 500 yards in length by 30 in breadth.

Here the next bed above the Chalk-rubble was a band of brown Boulder clay, with many stones. Of course, as this was a horizontal exposure, and the angle of dip being also uncertain, it was impossible to estimate exactly the thickness of this band, but it did not seem to exceed three or four feet.

As I do not know of another section in Yorkshire in

which the bottom of the "Basement" clay has been clearly seen, it is impossible to correlate this bed with any elsewhere, and equally impossible to say whether it is merely a local patch, belonging to the so-called "Basement" clay, or is really an older clay; but at Dimlington, south of Withernsea, where the thick "Basement" clay is seen in the cliff, the great depth which must occur between it and the chalk, which is far beneath the surface, renders it quite possible that there may be other glacial beds between them, older than this so-called "Basement" clay. If this be not the case, the "Basement clay" must be here of immense thickness.

The Boulder clay overlying this Brown band I immediately identified as being the same, in all respects, as the "Basement" clay at Bridlington and elsewhere. It was of a bluish tinge, and contained a considerable quantity of chalk. It also contained many shells of the same species as those found by me at Bridlington. But besides the shells, which were scattered indiscriminately through the clay in the same way as the boulders, and were generally broken, there were also some curiously-twisted streaks, formed in part of a fine blue clay, free from stones, and in part of a dark clayey sand. These streaks contained many shells, *Cardita borealis* being particularly abundant. Nearly all these shells were crushed, and the fragments somewhat separated, as though through the shearing of their clayey matrix. These streaks have their exact counterpart in similar, though more considerable, patches at Bridlington, which form outliers to the shelly mass long known as the "Bridlington Crag." They are probably the remnants of an old sea-bottom of sand and mud which the ice-sheet has almost obliterated, and from which come the shells now seen in this Boulder clay.

I do not know that this clay can be seen in the cliff anywhere in Filey Bay, and had I not witnessed this exposure, I should have remained ignorant of its presence there. It

has, no doubt, been at one time of far greater extent, and has been so extensively denuded as to leave but this patch remaining, nearly in the centre of the old valley.

The upper surface of this clay was very irregular, and here and there, there remained between it and the next Boulder clay patches of a Brown clay without stones, agreeing with the Middle Laminated Band which has its place between the Basement and the Purple clays at Bridlington.

Over these patches, and where they were absent, resting directly on the "Basement" clay, in strongly-marked contrast, was another Boulder clay, which was the highest bed seen in this exposure, and was continued into the cliff.

Where seen in the cliff, this bed is of a dark purple colour, and when dry has a decidedly greenish tinge. It contains a few shells and shell-fragments, and also pieces of chalk bored by *Pholades* and *Clionæ*.

It forms the base of the cliff from near Speeton to Filey, and is also well developed in Cayton Bay, at Scarbro', at Robin Hood's Bay, and at Whitby,—and in fact, in all the sections on the coast where the drift is of any depth.

It is sometimes of great thickness, as near Hunmanby Gap in Filey Bay, where it has a height in the cliff of over forty feet.

This Boulder clay, which is clearly the representative of the "Purple" clay division south of Flambro', has a very uneven upper surface, and in some of the hollows thus formed are gravels and the laminated warps which will be again referred to.

Over these, and where they are not found directly over the Greenish-Purple clay, is another Boulder clay of a well-pronounced brown colour, which is also often very thick. In cases where it rests directly on the Purple clay, without any intercalation (as at Hunmanby Gap, where there is one of the clearest examples of this kind), the only distinction

between them is in colour, and though this is so well-marked as to enable one to point out with certainty to the exact spot where the one ends, and the other begins, yet there are many who deem divisions marked by colour to be unsatisfactory, and who would therefore look upon this as insufficient evidence to warrant a separation.

Fortunately, however, testimony of a more convincing kind is not wanting to show beyond doubt that, even allowing for possible contemporaneous denudation, a considerable time must have elapsed between the formation of the lower Purple clay, and of the upper Brown bed. It is also a useful illustration of the value, as lines of separation in this part of Yorkshire, at least, of these definite colour partings.

The evidence referred to is found in the presence of a broad deep hollow in the lower clay, between Reighton and Hunmanby, which has not only been scooped out, but has also been completely filled in again with finely laminated sands and warps, in places nearly 40 feet thick, almost free from pebbles, save a few coal specks. On each side of the hollow, which is 500 yards across, the Brown clay rests directly upon the Greenish-Purple clay, but when it reaches the southern edge of the hollow, instead of following the steep cliff-like slope of the lower clay, it continues along the same level, thus admitting the intervention of the laminated warps, which completely fill the intervening space. These warps at first dip steeply down the side of the hollow, and are also slightly contorted towards the top, but for the most part they are very even and regular. The northern end of the hollow is much obscured by slips; but shortly after the laminated clays cease to be seen in the cliff, a clear section shows the two Boulder clays to be once more in contact.

This Brown clay is strongly developed in the cliff near Filey Brig, being there of great thickness, and still resting upon Purple clay with a green tinge.

It is also traceable along the coast as far as Whitby, beyond which I have not yet examined the sections.

It seems to have no representative at Bridlington, but reappears further south, between Hornsea and Withernsea, and is well seen at Dimlington, six miles south of the latter place. It does not seem to have been treated before as a separate clay, but it certainly has as good a right to be so considered as have any of the other divisions.

It contains a few small shell fragments.

The next Boulder clay, which nearly always forms the top of the cliff, is red in colour, and shows, in some places, ashy-blue facing to its fissures.

In these sections it but rarely attains to, and never exceeds, a thickness of 12 feet. It is more earthy and broken than any of the other clays, and contains few stones of any size. Amongst its few Boulders, however, I noticed a piece of shale which showed very distinct scratches.

It sometimes lies directly on the Brown clay, in which case the division between them is not very distinct, but oftener a band of sand and gravel separates them. This gravel, which is often very coarse and bouldery, is generally from one to four feet in thickness; but just north of Hunmanby Gap it swells out so as to have a thickness of nearly thirty feet, and here the top red clay passes into it for a short space. These gravels, also, sometimes admit into their midst a thin band of very dark greenish boulder clay, which is not, however, regular and continuous enough to be separated from them.

I do not hesitate to identify this top red clay, which forms the capping bed to nearly all the sections between Speeton and Filey, with that to which, on the Holderness coast, Messrs. Wood and Rome have given the name of "Hessle Clay," and which, as is mentioned in the commencement of this paper, these gentlemen have traced inland "through the vale of York into that of the Tees;" but

which they do not seem to admit into the coast sections north of Flambro.

The complete Filey Bay section, therefore, would appear to stand as follows. Commencing at the top:—

SECTION.	CORRELATIONS.
<i>Full section in Filey Bay.</i>	<i>Already recognised divisions elsewhere.</i>
1. <i>A band of Red Clay</i>	= <i>Hessle Clay.</i>
1A. <i>Gravels, with a band of Dark Boulder Clay—not continuous</i>	= <i>Hessle Gravels.</i>
2. <i>Brown Clay, sometimes very thick</i>	Not before separated.
2A. <i>Gravels, Sands, and Laminated Clays—not continuous</i>	
3. <i>Greenish-Purple Clay, sometimes very thick</i>	= <i>Purple Clay.</i>
3A. <i>Patches of clean Brown Clay</i>	= <i>Laminated Band</i> at Bridlington.
4. <i>Blue Clay, with Shells</i>	= <i>Basement Clay.</i>
5. <i>Band of Brown Clay</i>	No known equivalent.
6. <i>Chalk Rubble, with Sand containing Shells</i>	= Similar beds at Danes' Dykes, &c.

With the exception of the bottom band of Brown Clay, these beds have all their representatives in the cliff at Dimlington, south of Withernsea, as the following section, taken near where the cliff is highest at Dimlington, will show. At the top of the cliff:—

Dimlington:—

	<i>Messrs. Wood & Rome's Divisions.</i>
1. Red Clay, with Blue Facings	= Hessle Clay.
1A. Patches of Gravel	= Hessle Sands and Gravel.
2. Brown Boulder Clay	= Purple Clay without Chalk.
3. Boulder Clay, greenish at the top, but changing downwards into a dark purple, with much Chalk	= Purple Clay with some Chalk.
4. Greenish Blue Clay, with many Shells	= Basement Clay.

Though in this section the Hesse and Brown Clays alone are divided by sand or gravel beds, still, if either of the other lines of division be followed for a short distance, thick sands make their appearance, and separate the clays most distinctly.

Though Mr. S. V. Wood notices here the peculiarity in what he has termed the Upper part of the Purple Clay, he does not seem to think it was entitled to be considered as of separate age; but it seems to me, that if divisions are made at all in the Yorkshire clays, this must be accepted as one.

In conclusion, it will, perhaps, be of value to briefly recapitulate the evidence on which the divisions of the Drift in Filey Bay here proposed rest.

To begin with the lowest bed:—the bottom Brown Band, with many stones, showed itself on the beach in very decided contrast with the overlying Blue Clay. But as this is at present the only notice of this bed, it would be premature to separate it. By doing so also, we should make the term "Basement," by which the next clay is known, in this case at least, a misnomer. Pending further evidence, it will therefore perhaps be better to class it provisionally with the Basement clay.

Though in Filey Bay the Basement clay, which includes glacial shelly bands both at Bridlington, Dimlington, and here, is only separated from the overlying Boulder clay by an uneven surface, and strongly marked line, along which patches of clay free from stones occur at intervals, at Bridlington this same line is marked by the presence of a very finely laminated, and in some places ripple-marked, clay which has filled up the inequalities of its denuded surface to a depth of 16 feet, just south of Bridlington, as was shown in the workings in connection with the sea-wall now being erected there. At Dimlington, also, the same line is marked by thick sands and laminated clays.

The next clay, which forms the lower part only of the division known as the Purple Clay of Mr. S. V. Wood, is, as I have attempted to show, clearly divided from the overlying Boulder clay, not only by its lithological characters,—for those I put out of the question for the present,—but by the evidence of a denuded surface, which admits into its hollows gravels and laminated clays of great thickness,—in one case a mass of the latter being over thirty feet thick, a deposit which must have required a long time to accumulate.

The Brown Boulder clay, which comes next in succession, is separated from the top Red Band by gravels, more or less continuous, which are in one place at least 30 feet thick, and which sometimes admit into their midst a distinct band of dark Boulder clay, which, though it does not continue far, clearly shows that time must have elapsed between the formation of the one and the other.

In this estimate of the value of these lines of division, I have purposely omitted all reference to the well-marked lithological differences, such as in colour and texture, and in the quantity and character of the included boulders; and to the palæontological distinctions, in the comparative abundance, or rarity, of shell fragments, as effects like these *might* have been caused by changes in the direction or conditions of the ice-flow.

But when these points are taken in conjunction with the presence of the intercalated beds which I have just recapitulated, it seems to me that the sum of evidence thus obtained shows clearly that these beds could not have been accumulated by a continuous and unbroken period of ice-action.

It also shows that there are lines whose claims have been hitherto overlooked, which may be quite as worthily used in dividing these clays as any of those now acknowledged.

It remains to be proved by further research which are the most important of these divisions, but I think it will be found

that the "Basement" and "Purple" clays have their greatest development in Holderness, whilst the "Purple" and "Brown" predominate north of Flambro',—the Hesse capping all.

There is no space within the limits of the present Paper to point out the important bearing of some of these facts on the several theories advanced as to the mode of formation of these clays, but I hope on some future occasion to be able to do so.

THE SOURCE OF THE RIVER AIRE. BY THOMAS TATE, F.G.S.

"*ARUS ex Pennigenti montibus radicibus ortis.*"* This was the opinion of the great topographer, Camden, the earliest on record.

Hurtley, the Malham schoolmaster, writing of Malham Water—"a lake embosomed in the cloud-capt mountains"—describes it as "the fountain of the river AIRE, which, hiding itself, as it were, immediately on its escape from its parent's confines, traverses the bowels and cavities of the earth till it finds a snug and secure retreat amid the almost inaccessible crags at the foot of the Cove."†

The relative claims of the different feeders are fully discussed by Whitaker:—"Speaking in general terms, the lake may fairly be considered as the source of the Aire; but as its outlet quickly sinks into the ground, and is lost, and as several streams which appear below contend for the honour of the connection, it still remains a matter of some uncertainty to which of them the preference is to be given.

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* "*Britannia*," 1st ed. (1590), page 559. "Leland saith it riseth neere unto Orton in Craven," Harrison (1577) "*Description of Britaine*." This is mere hearsay, Leland never having visited the district. The quotation is unaccompanied by any reference, and I have not been able to meet with it in the "*Itinerary*."

† "*Natural Curiosities of Malham*" (1786), page 34.