

CHAPTER XXV.

EAST YORKSHIRE.

By R. S. HERRIES, F.G.S.

BY East Yorkshire, for the purposes of this article, I mean that part of the county which lies east of the belt of Triassic strata which stretches north and south from the Tees to the Humber, occupying the low-lying tract known in various parts as the Vale of Cleveland, the Vale of Mowbray and the Vale of York. The district has been visited by the Association on three occasions, namely, in the years 1875, 1891, and 1906, and the coast sections have been examined from Redcar to Bridlington, as well as certain of the neighbouring inland sections; and as future excursions are likely to be on the same lines, I propose in this article to describe the coast section in more detail, dealing very shortly with the more westerly parts of the district, except where any special point of interest should require longer treatment.

PHYSICAL FEATURES.

The dominant features of the district are two hilly regions, very distinct in character, that in the north being known generally as the Moors, that in the south as the Wolds. These are separated by the broad west and east valley known as the Vale of Pickering. The Moorland district consists of Jurassic hills much intersected with deep valleys, called dales, and occupies the whole country between the Tees and the Vale of Pickering in one direction, and the Vale of Mowbray and the sea in the other. About midway between the Tees and the Vale of Pickering it is divided into two parts by the considerable river Esk, which flows into the sea at Whitby, being the only river (other than small becks) between the Tees and the Humber which finds an outlet to the coast. This moorland tract is, as the name implies, barren in character, especially in the more northerly parts, where the surface mostly consists of one or other of the sandstones of the Lower Oolites, one of which is characteristically known as the "Moor Grit," though the soil in the dales, especially when composed of glacial drift, is often fertile enough.

Certain of these dales, all cutting down into the Lias, are ranged in a curious radiating fashion on either side of a ridge which runs parallel to and south of the Esk, and forms the highest ground of the whole range, Burton Head being 1,489 feet above

the sea. On the north side of the ridge from west to east are Basedale, Westerdale, Danbydale, Fryupdale, and Glaisdale, opening into the Esk, while more or less corresponding on the south side are Bilsdale, Bransdale, Farndale, and Rosedale, opening into the Vale of Pickering. Farther east there is a pass between Goathlanddale on the north and Newtondale on the south, by which the railway runs from York to Whitby.

The greater part of this district consists of Lower Oolites, with Lias in the valleys and on the lower slopes, and goes by the name of the *Cleveland Hills*. The southern part, however, forming a broad strip overlooking the Vale of Pickering, and stretching from Scarborough on the east to the Vale of Mowbray between Northallerton and Thirsk on the west, is formed of beds of Middle Oolite, capped generally by Coralline Oolite or Calcareous Grit. These hills have a very distinct character, being generally flat-topped and less irregular in outline than those of the Lower Oolite district. Phillips gave them the name of the *Tabular Hills* from their appearance, and at their western end, where they rise in a grand escarpment above the Vale of Mowbray, they are known as the *Hambleton Hills*.

There is another set of Oolitic Hills, the *Howardian Hills*, on the south side of the Vale of Pickering, ranging from the comparatively low faulted ground at the head of the Vale about Coxwold to the neighbourhood of Malton, where they abut against the Wolds, the strata of which they are composed passing unconformably under the Chalk. These hills, which get their name from the estate of Castle Howard, consist of Middle and Lower Oolites, and are of much less elevation than the Moors, though they are interesting from a geological point of view as presenting many differences in character from the beds of the coast section.

The Wolds are a range of Chalk hills which enter the county from Lincolnshire near North Ferriby, on the Humber, and run in a northerly direction as far as the neighbourhood of Malton, when they turn eastwards, and, forming the southern boundary of the Vale of Pickering, run out to sea in the fine promontory of Flamborough Head. They present the usual character of Chalk Downs and slope to the east and south, being masked on their slopes by the beds of glacial drift which form the greater part of the district, between them and the sea, known as Holderness. On the escarpment side they are seen to overlap and rest unconformably on the various beds of the Jurassic Series. Thus the beds of the Howardian Hills, which as already mentioned abut against the Wolds near Malton, dip generally towards the Vale of Pickering, while the Chalk of the Wolds is dipping away from the Vale to which it presents an escarpment.

The Vale of Pickering is a broad valley with a sub-soil of Kimeridge Clay, which has a somewhat peculiar history. It is

naturally the valley of the Rye and its tributaries flowing from the Hambleton and Cleveland Hills. At one time this river no doubt pursued an uninterrupted eastward course to the sea at Filey Bay. Now, however, about half way down the valley it suddenly makes a complete double on being joined from the north-east by the Derwent, which has broken through the Tabular Hills from the moors at the back of Robin Hood's Bay by the gorge of Forge Valley. The river, which henceforth takes the name of the Derwent, now flows westwards parallel to the Rye till it turns south at Malton and breaks through the Howardian Hills by the gorge of Kirkham Abbey, whence it pursues a more peaceful course through the low lands of the plain of York to join the Ouse near where it merges into the Humber. The cause of this behaviour of the rivers will be discussed when dealing with the glacial drift.

I have said that the district is bounded on the west by the Triassic Valley. On the north and east it is bounded by the sea, and the coastline affords a long stretch of magnificent sections.

The coast is divided by Flamborough Head into two distinct parts, of which the northern is rather the larger. South of this point there is not a scrap of solid geology to be seen, the whole coast of Bridlington Bay being made up of clays, sands and gravels of the Glacial Series. The northern section is again nearly equally divided between the outcrop of the Cretaceous, Neocomian, and Oolitic beds to the south, and the Liassic sections to the north, the dividing point being Blea Wyke just to the south of Robin Hood's Bay.

GEOLOGY.

The geology of Yorkshire, from the Mesozoic period onwards, has so much to distinguish it from other parts of England that it may fitly be considered as a province apart. The Lias is developed zone by zone in a way that is exceptional, but it does not otherwise present features very different from other parts. Economically it has always been noted, formerly for the alum extracted from the Upper Lias Shales, and for the jet found in the harder beds immediately below, and now for the rich iron-stone beds of the Middle Lias. When, however, we come to the Lower Oolites we have a great series of Estuarine beds with certain thin but persistent marine beds separating them into Upper, Middle, and Lower. These marine beds all correspond to different horizons of the Inferior Oolite of the south of England, so that when the Cornbrash is found succeeding the Estuarine beds, apparently without a break, it is clear that the Bathonian,

if represented at all, must correspond with the Upper Estuarine or part of it. It is true that these Estuarine beds exist in Lincolnshire and the adjoining counties, though they are not so largely developed.

Higher up in the succession we find exactly the opposite. While the great deposits of Purbeck and Wealden strata of freshwater or estuarine character were being laid down in the south of England a great marine series was in course of formation in Yorkshire (as well as in Lincolnshire) known as the Speeton Clay, the upper part of which represents also the Lower Greensand of the south. Then again, while the great limestone series of the Bath and Portland Oolites of the south are not represented as such in Yorkshire, the calcareous character of the Coralline Oolite, which all through the Midlands has disappeared, reasserts itself with great strength in Yorkshire, whether as grit, coral rag, or limestone proper.

The absence of Tertiary Beds is not peculiar to Yorkshire, but may be mentioned to complete the contrast with the south of England.

J. F. Blake* attributed these striking differences to a separation of Yorkshire from the surrounding districts by an axis of elevation which began to be marked in Carboniferous times, running from the Humber to the Tees, and it seems clear that something of this kind must have been the case.

Subjoined is a list of the Cretaceous and Jurassic Rocks as exposed on the Yorkshire coast :

- Upper Chalk.
- Middle Chalk.
- Lower Chalk and Chalk Marl.
- Red Chalk (Gault).
- Speeton Clay (Neocomian and Portlandian).
- Kimeridge Clay.
- Corallian.
- Oxford Clay.
- Kellaways Rock.
- Cornbrash.
- Upper Estuarine Series.
- Grey Oolite, or Scarborough Limestone.
- Middle Estuarine Series.
- Millepore Oolite.
- Lower Estuarine Series (with Ellerbeck Bed).
- The Dogger (with Blea Wyke Beds below).
- Upper Lias (Shales).
- Middle Lias (Ironstones and Sandstones).
- Lower Lias (Shales and Limestones).

* "The Geology of the Country between Redcar and Bridlington," by J. F. Blake *Proc. Geol. Assoc.*, vol. xii, p. 115.

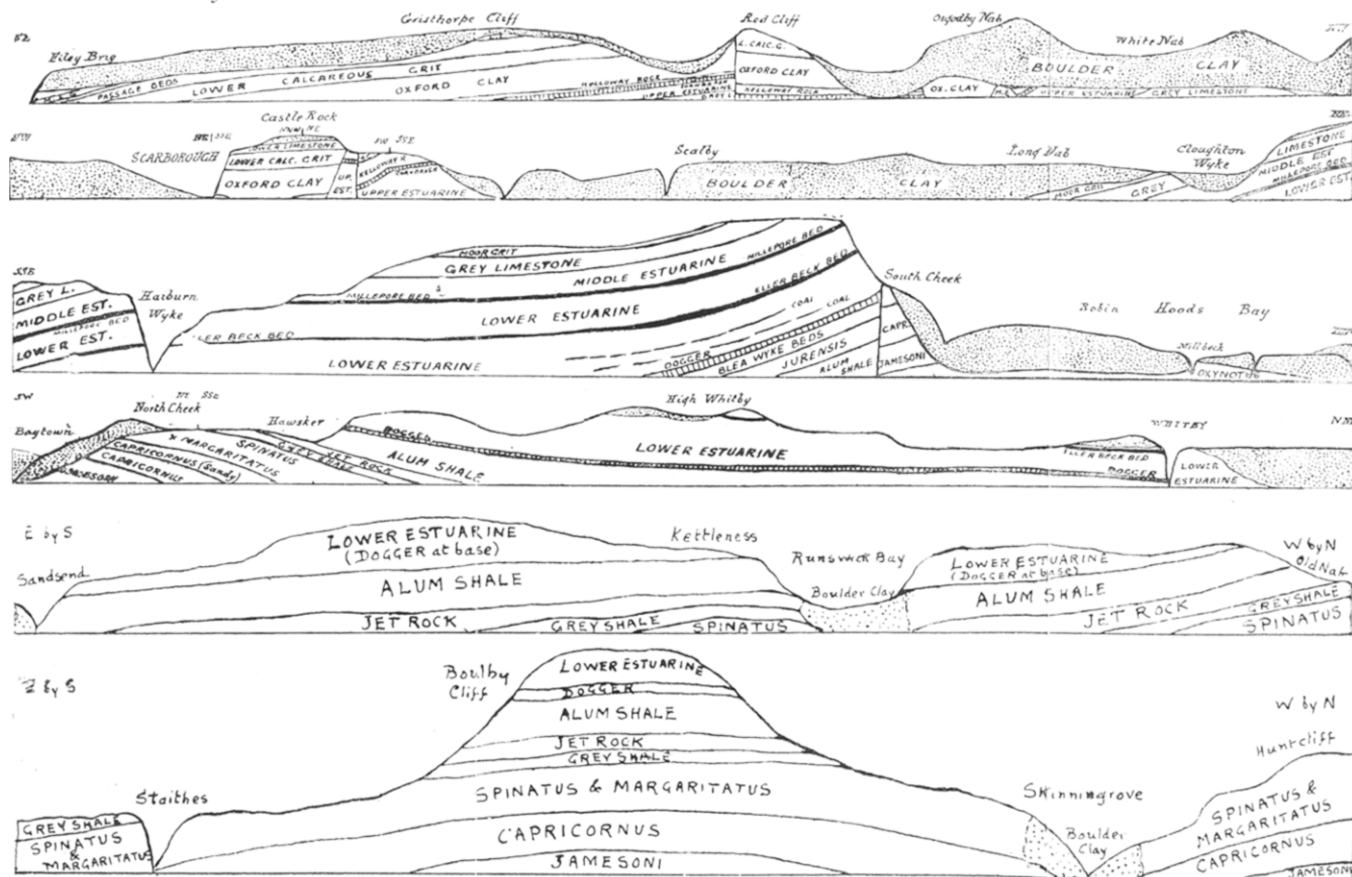
Plate XVIII is a section of the coast from Filey Brig to Hunt-cliff just south of Saltburn, so that it includes all the solid geology except the Chalk and Speeton Clay. It will be seen that, generally speaking, there is a southerly dip, so that in going from south to north we pass from newer to older beds—that is to say, from the Chalk at Bridlington to the *Angulatus* Beds of the Lias at Redcar, a little north of the section. There is, however, a faulted anticline at Red Cliff, another considerable anticline at Robin Hood's Bay, a third between Staithes and Saltburn, and a fourth between the latter place and Redcar. The principal faults are those at Red Cliff, Scarborough Castle, the Peak (South Cheek of Robin Hood's Bay), and Whitby Harbour.

THE LIAS.

This great formation is usually divided into Upper, Middle and Lower Lias, the Upper and Lower being for the most part clays, with limestones in the lower beds, and the Middle, ironstones, sandstones, and "marlstones." The Lias is now, however, more generally divided into zones, of which certain Ammonites form the indices, and as the boundaries of these zones do not always coincide with lithological changes, some little confusion of terms has been brought about. The division of the Lias into zones was first made by Oppel in 1856, and was applied to this country by Thomas Wright in 1860. In their monograph on the Yorkshire Lias, published in 1876, Tate and Blake adopted this system, and so far as Yorkshire is concerned, the divisions which they adopted stand to-day as well as they did 30 years ago. Their classification was as follows in descending order, and for convenience I have added the grouping of the Geological Survey :

Zone of <i>Ammonites</i>		Survey. T. & B.	
	<i>jurensis</i>	}	UPPER LIAS.
"	<i>communis</i>		
"	<i>serpentinus</i>		
"	<i>annulatus</i>		
"	<i>spinalus</i>	}	MIDDLE LIAS.
"	<i>margaritatus</i>		
"	<i>capricornus</i>		
"	<i>jamesoni</i>		
	(with sub-zone of <i>A. armatus</i>)	}	LOWER LIAS.
"	<i>oxynotus</i>		
"	<i>bucklandi</i>		
"	<i>angulatus</i>		
"	<i>planorbis</i>		

The grouping into Upper, Middle, and Lower Lias by Tate and Blake differed from that previously adopted by largely increasing the thickness of the Middle Lias. They no longer adopted a lithological grouping, but, in conformity with their system of zones, they also arranged the larger groups



SECTION ON THE YORKSHIRE COAST FROM FILEY BRIG TO HUNTCLIFF.

Filey Brig to Whitby, by J. F. Blake (*Proc. Geol. Assoc.*, vol. xii, p. 116); Sandsend to Huntcliff, by R. S. Herries (*ibid.*, vol. xix, p. 414).

N.B.—The apparent dislocation of the strata at Runswick Bay is due to an error in drawing. The lines on the left are drawn too high up, the Jet Rock being very near the shore where cut off by the Boulder Clay. The beds, however, are curiously irregular here. The apparent depression at Skinningrove is caused by the southerly or inward dip of the beds, the lowest of which do not therefore appear in the bay, but only at the points.

according to the principal palæontological changes. They say very truly that the most obvious change in the fauna as you examine the series from below upwards is when the *Armatus* beds set in, and again a considerable break in everything except the ammonites occurs at the top of the *Annulatus*-zone. The officers of the Geological Survey in mapping the Upper, Middle, and Lower Lias found it necessary to draw their lines in accordance with the lithological differences. Apart from the difficulty of drawing lines on palæontological grounds, in places where there are no sections yielding fossils, there is a practical question, which is that the people, for whose use the maps are supposed to be constructed, do not so much trouble themselves about what life zone their houses or fields may be situated on, as they do whether they are on sand, clay, or limestone, or whether there is a reasonable chance of finding one or other of these lithological divisions if they excavate below the surface soil.

The Survey therefore draw the division between the Upper and Middle Lias above the Ironstone Series, that is to say, at the base of the *Annulatus*-zone, or Grey Shales, as they are often called. The line between the Middle and Lower Lias is drawn at the base of the sandy series, and the former therefore includes the zones of *Am. spinatus*, *Am. margaritatus*, and the upper part, about 30 ft., of the zone of *Am. capricornus*, for it is in this zone that the change from shales to sandstones begins. The line is therefore in the middle of a zone, which may be inconvenient for collectors. There is no reason, however, why the latter should trouble themselves about the divisions of Upper, Middle, and Lower. All they need do is to note the zone in which they are working, and this can in general be ascertained from the fossil contents. I say "in general," because there is a considerable amount of overlapping at the boundaries of the zones, and many of the species pass through several zones. Tate and Blake in describing the continuous sections to be found along the coast were obliged to commit themselves as to where one zone began and another ended, and it is of course possible in some cases for subsequent workers to criticise their decisions, but not so easy to establish an alternative line. A particular instance may be mentioned both in the upper and lower limits of the zone of *Am. margaritatus*. It would be quite reasonable to put rather more of the upper beds into the zone of *Am. spinatus*, while the division adopted by Tate and Blake between the zones of *Am. margaritatus* and *capricornus* seems rather arbitrary, making it very difficult to assign fossils collected from fallen blocks to their proper zone. In fact the zone of *Am. margaritatus* in Yorkshire might very well be abolished and the beds divided between the zones immediately above and below, but as it is established in other places it is more convenient to keep it, and this is probably what Tate and Blake thought. These, however,

are minor details, and it must be remembered that "a zone does not constitute a hard and fast line, to which the characteristic ammonite or whatever fossil may be taken as the type is restricted, but merely implies that that species is more abundant there than elsewhere, and that the other fossils with which it is associated constitute a general assemblage which marks out that particular horizon as sufficiently distinct from the rest of the formation."* Except, therefore, in cases where it can be established that a particular fossil, or some variation, does not pass out of a particular zone, and that fossil is present, it must be left to some extent to the judgment of individual collectors, especially in isolated sections, to decide in which zone they are working. As a rule, however, the ammonites used as indices of the zones in Yorkshire are very well chosen, and it will be universally admitted that in the case of the Lias no better fossil than the ammonite could be selected. Other zones or regions could be established, no doubt, but no other genus or family could be taken and made to do duty right through. Belemnites have been used in some formations, e.g., by Mr. Lamplugh for the Speeton Clay, but in the Lias their range is much less restricted than is that of the ammonites, though certain of them might be used to mark regions or sub-zones. Thus the zone of *Am. serpentinus* might be sub-divided into a lower region containing *Bel. tripartitus* and an upper with *Bel. tubularis*. Then, again, such a zone as *Am. jamesoni* might with great exactitude be indicated by *Pinna folium* or *Plicatula spinosa*, both of which fossils are extremely abundant in, and are practically restricted to this zone, including its sub-zone of *Am. armatus*, whereas the index ammonite is confined to the upper part and is not very characteristic except locally. It is, however, much more convenient to adhere to one set of fossils for the indices right through, as otherwise it would be difficult to avoid some confusion and overlapping, though the plan of varying the index fossil seems to answer in the Chalk.

We may now describe the zones in more detail. The zone of *Am. planorbis* does not occur on the coast in Yorkshire, though its existence is proved in pits sunk at Coatham and Eston in the north of Cleveland. Blocks of limestone containing the index Ammonite, or one very closely allied to it, are washed up from time to time along the coast, or are found in the Boulder Clay. The best sections of these beds inland are at North Cliff, near Market Weighton, in the East Riding, where the beds consist of about 55 ft. of alternations of blue clay with thin beds of sandstone and limestone. Among the fossils are *Ammonites planorbis*, *Am. johnstoni*, *Ostrea liassica*, and *Pleuromya crowcombeia*.

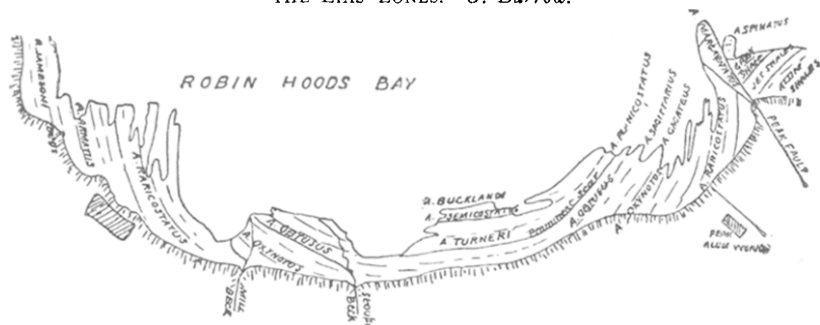
The zone of *Am. angulatus* is only exposed on the coast at Redcar in the scars nearest the shore. It dips under the

* C. Fox Strangways, *Mem. Geol. Surv.*, "The Jurassic Rocks of Britain," vol. i, p. 27, and see H. B. Woodward "On Geological Zones," *Proc. Geol. Assoc.*, vol. xii, p. 295.

Bucklandi beds, and forms the lowest visible bed of the anticline, though it is possible that if the sand of the beach were all removed still lower beds might be seen. About 30 ft. of beds are seen consisting of blue shales and limestones alternating. The zone is also well seen inland at North Cliff overlying the *Planorbis* beds. The fossils include *Ammonites angulatus*, *Pleurotomaria anglica* (*similis*), *Gryphæa arcuata* and *Cardinia listeri*.

The zone of *Am. bucklandi* is exposed at Redcar at low water in a series of flat scars coming out underneath the sands which stretch from Redcar to Saltburn. The beds consist of alternations of shales and limestones, and the thickness is about 180 ft. The beds, which are extremely fossiliferous, dip to the north-west. About two miles farther east, in Marske Bay, beds are sometimes exposed, the fossils in which show that they belong to the *Bucklandi*-zone, dipping to the south-east, showing that in

FIG. 105.—PLAN OF THE SHORE IN ROBIN HOOD'S BAY SHOWING THE POSITION OF THE LIAS ZONES.—*G. Barrow.*



[“*Explanations des Excursions*, Cong. Géol. Int., 1888, p. 138.]

the Redcar and Coatham Scars we are dealing with an anticline. This zone also forms the most seaward of the scars at Robin Hood's Bay in two portions, one between Mill and Stoupe Becks, and the other farther to the south towards the Peak. The beds, which again consist of alternations of limestones and shales, are about 30 ft. thick, only the upper part of the zone being represented (see Fig. 105). The beds are also seen inland in the southern part of the county near Kirkby Underdale, etc.

Among the principal fossils are *Ammonites bucklandi*, *Am. conybeari*, *Am. birchii*, *Am. turneri*, *Am. semicostatus*, *Nautilus striatus*, *Belemnites acutus*, *Bel. infundibulum*, *Cryptenia solarioides*, *Pleurotomaria anglica (similis)*, *Turritella dunkeri*, *Gryphaea arcuata*, *Pecten textorius*, *Lima gigantea*, *Leda galathea*, *Astarte obsoleta*, *Cardinia listeri*, *Pholadomya ventricosa*, *Pleuromya liasina*, *Montlivaltia haimeie*, *M. guettardi*.

The zone of *Am. oxynotus* is beautifully exposed at Robin

Hood's Bay, on the scars of which the beds stretch in a sort of semi-circle from Bay Town to Peak Steel, where they are cut off by the fault (see Fig. 105). They rise into the cliff near the old alum works and come down again near Mill Beck. The thickness is about 100 ft., and the beds consist of blue and grey shales often much indurated, separated by strong calcareous layers. The only other exposure on the coast is in a reef between the Redcar and Coatham Scars known as High Stones. The *Oxynotus* Beds are sometimes sub-divided into the zones of *Am. raricostatus*, *Am. oxynotus*, and *Am. obtusus* in descending order, and these subdivisions hold good fairly well at Robin Hood's Bay. The fossils in these beds are numerous, and there is a great variety of ammonites. Among others we find *Ammonites oxynotus*, *Am. raricostatus*, *Am. impendens*, *Am. gagateus*, *Am. obtusus*, *Am. sagittarius*, *Am. stellaris*, *Am. planicostatus*, *Nautilus intermedius*, *Belemnites acutus*, *Bel. infundibulum*, *Gryphæa arcuata*, *Pecten priscus*, *Monotis inæquivalvis*, *Modiola scalprum*, *Leda galathea*, *Hippopodium ponderosum*, *Cardinia listeri*, *Pentacrinus tuberculatus*, *P. basaltiformis*.

The zone of *Am. jamesoni* is seen on the upthrow side of the Peak fault, where at the base of the cliff it is contiguous to the beds of the *Serpentinus*-zone. On the other side of the Robin Hood's Bay anticline it forms the cliff on which Bay Town is built, and the scars opposite the town, passing under the beds of the zone above before the North Cheek is reached. It is next brought partly up by a low anticline, first under Boulby and then under Huntcliff, and is last seen forming the innermost reef of the Coatham scars. The beds of this zone consist of a series of micaceous shales and red doggers. The thickness at Robin Hood's Bay is about 200 ft., of which the lower 90 ft. are reckoned by Tate and Blake as belonging to the sub-zone of *Am. armatus*. These lower beds are extremely rich in fossils, which often occur in pyritous nests. The fossils are of very great interest, especially the ammonites and belemnites, which latter are very abundant. *Pinna folium*, *Plicatula spinosa*, *Chemnitzia blainvillei*, and *Spiriferina walcotti* are very characteristic. Drift wood is particularly abundant in these beds. The beds are seen in several places under the Wolds in the East Riding, as at Warter, near Pocklington.

Besides those mentioned above, the following, among other fossils, occur: *Ammonites jamesoni*, *Am. brevispina*, *Am. striatus*, *Am. armatus*, *Am. trivialis* (*polymorphus*), *Belemnites elegans*, *Bel. virgatus*, *Bel. araris*, *Bel. clavatus*, *Gryphæa cymbium* (var. *obliquata*), *Pecten æquivalvis*, *P. priscus*, *Limea acuticosta*, *Monotis inæquivalvis*, *Modiola scalprum*, *Leda galathea*, *Protocardium truncatum*, *Unicardium cardioides*, *Pholadomya decorata*, *Waldheimia sarthacensis*, *Rhynchonella tetrahedra*, *R. variabilis*, *Ditrupea capitata*, *Hemipedinia* sp.

The zone of *Am. capricornus* is first seen in the cliff at Peak, faulted against the Lower Estuarine Beds and Dogger (see Fig. 107). On the other side of the anticline it forms the upper part of the cliff stretching from Robin Hood's Bay Town to the North Cheek, before which point it has come down to the shore and forms the scar as far as Castle Chamber (see Fig. 106). It does not appear again above the sea level till Staithes is reached, where it forms the lower part of Colburn Nab, and the scars nearly as far as Boulby Cliff, where it rises in the cliff to come down at Hummersea, of which cliff it forms the lower 50 ft. or so. On the other side of Skinningrove it rises again in the face of Huntcliff, beyond which it is masked by the Boulder Clay. Afterwards it is only seen on the Coatham scars, where it cannot be favourably examined. These beds are divisible into two lithological groups, the upper of which consists of calcareous sandy beds characterised by the occurrence of starfish and other echinoderms which may be found at Staithes, and in fallen blocks at Robin Hood's Bay, Boulby, and Huntcliff. They are also marked by oyster beds (*Gryphæa cymbium*, var. *depressa*), and there is one layer at Castle Chamber which is a mass of *Dentalium giganteum*. The beds below are grey sandy shales with lines of red doggers, many of which contain the zonal ammonite, and one particular layer near the base of the series almost always contains *Am. fimbriatus*. The thickness of the beds is generally from 120 to 140 ft., of which the upper 30 ft. or so belong to the sandy series.

Besides the above-named fossils the following occur:—*Ammonites capricornus*, *Am. defossus*, *Am. henleyi*, *Belemnites elongatus*, *Bel. apicicurvatus*, *Bel. aspergillum*, *Bel. clavatus*, *Chemnitzia blainvillei*, *Eucyclus undulatus*, *Pecten æquivalvis*, *P. calvus*, *Monotis inæquivalvis*, *Inoceramus ventricosus*, *Modiola scalprum*, *Protocardium truncatum*, *Pholadomya ambigua*, *Ophioderma milleri*, *O. carinata*, *Astropecten hastingiæ*, *Cidaris edwardsi*, *Pentacrinus interbrachiatus*.

The zone of *Am. margaritatus*, or "Marlstone" series, is, as already explained, very closely bound up with the Ironstone series, though the lower half might well be united with the upper part of the *Capricornus* beds below. It appears first on the scar at Peak Steel both in the fork of the faults (see Fig. 107) and on the south side faulted against itself. On the other side of the anticline it comes down to the shore at Castle Chamber, and occupies the foreshore of the little bay till the *Spinatus* beds come down near Hawsker Bottoms (see Fig. 106). We do not see these beds again till a little east of Staithes, when they appear on the shore and ascend into the cliff. They are seen in the face of Boulby and Hummersea Cliffs, and again at Huntcliff, where they supply a large number of the huge fallen blocks, which form such a feature at the base of the cliffs. The only other exposure is in the

forming the southern half of the long reef of rocks stretching out to sea, known as Peak Steel. It is faulted against the *Margaritatus* beds which are here wedged in by a fork of the main fault (see Fig. 107). The beds are at the top of the cliff at the North Cheek and come down till they run out in scars at Normanby Styte Batts, under Hawsker Bottoms. They next appear from under the Grey Shales at Kettleiness, where they occupy the scars and the base of the cliff. On the west side of the point the beds are depressed below the Grey Shales, but come up and form the scars again, passing once more below the Grey Shales about the middle of Runswick Bay. They next come to the surface in Brackenberry Wyke, and form the headland of Old Nab, just east of Staithes, beyond which place they rise in the cliff, though obscured by Boulder Clay, till Boulby is reached, where they are about half-way up. Just before reaching Hummersea there is a fine exposure of the edges of these beds on the scar, caused by a great slip from the cliffs above. Every bed can here be easily measured. In place they form the upper part of the Hummersea cliff, and occupy a similar position at Huntcliff. The *Spinatus* beds consist generally of grey, sandy shales, with lines of ferruginous doggers which vary very much in thickness. At Hawsker the lines of doggers are only a few inches thick, but they increase towards the north and north-west, till at Eston, near Middlesbrough, the "Main" seam of ironstone is 11 ft. thick, besides which there are the "Pecten" seam, 4 ft. 6 in., and the "Two-foot" seam, 2 ft. 1 in. At Kettleiness the "Main" seam is in two blocks, 1 ft. 9 in. and 1 ft. 6 in., while at Staithes the blocks are 3 ft. and 2 ft. 2 in. At the great slip near Hummersea the "Main" seam is 8 ft. 9 in., of which 1 ft. in the middle is shaly, and the "Pecten" seam is 3 ft. 6 in., of which about half is shale, and the "Two-foot" seam is 1 ft. 3 in. The total thickness of the beds, according to Tate and Blake, is from 30 to 40 ft., but the officers of the Geological Survey would include rather more beds in this zone, which Tate and Blake had put into the *Margaritatus*-zone. They would give a thickness to the zone of 50 to 60 ft. The fossils in the Ironstone series are numerous and interesting, and very many species of gasteropods have been obtained by the careful researches of Tate and Blake.

The following among others occur:—*Ammonites spinatus*, *Am. margaritatus*, *Am. ferrugineus*, *Belemnites breviformis*, *Bel. cylindricus*, *Bel. apicicurvatus*, *Bel. clavatus*, *Cryptenia expansa*, *Eucyclus cingendus*, *Cerithium liassicum*, *Turbo acicula*, *T. cyclostoma*, *Pecten æquivalvis*, *P. lunularis*, *Monotis inæquivalvis*, *M. cygnipes*, *Modiola scalprum*, *Limæa acuticosta*, *Pleuromya costata*, *Rhynchonella tetrahedra*, *Terebratula punctata*.

The zone of *Am. annulatus* is usually spoken of as the "Grey Shales." It first occurs on the scars close to the Peak fault,

when, like the other beds, it is cut off and next appears at the top of the cliff at the North Cheek of Robin Hood's Bay, coming down to the shore at Hawsker Bottoms, where it may be well seen. It is next observed on the scar beyond Sandsend at Overdale Wyke, and again on the scars on both sides of Kettleness, rising into the cliff at the point. In Runswick Bay and Rosedale and Brackenberry Wykes it is on the scars, after which it rises in the cliff as far as Staithes, and is seen on the face of Boulby Cliff, and lastly it is found just at the top of Huntcliff. The beds, which are not of much interest, are about 30 ft. thick, and consist of grey crumbling shales. They are marked by the presence of *Am. annulatus*, which generally occurs in a particular band of rather flattened nodules. *Belemnites cylindricus* is also characteristic, though it passes up from the zone below. Other fossils are :—*Am. semicelatus*, *Cerithium liassicum*, *Monotis inaequalis*, *Gresslya intermedia*, *Leda galathea*.

The zone of *Am. serpentinus* is frequently referred to as the "Jet Rock," though the name should in strictness be confined to the lower part, as it is only there that that mineral is found.* The beds are easily traced by the old workings. Jet is still sought for, but not to a large extent, the demand having decreased, partly owing to the dictates of fashion, and partly because of the cheap imitations with which the market has been flooded. The zone is first met with at the Peak where it forms the base of the cliff at the fault, and here one can stand and pick out specimens of *Inoceramus dubius* with one hand, and characteristic *Jamesoni*-zone fossils with the other. It has been largely worked at the top of the cliff north of Robin Hood's Bay, and it is well seen on the foreshore at Hawsker Bottoms and at Saltwick, where it forms the base of Saltwick Nab and the Black Nab, as well as the reefs which stretch across the bay farther out. It has been worked all along from Sandsend to Runswick, and nearly to Staithes, and is again conspicuous in the upper part of Boulby Cliff. The *Serpentinus*-zone consists of about 90 ft. of hard dark blue shales, with lines of hard pyritous doggers. In the lower part, or Jet Rock proper, these are very large and form two or three strong, almost continuous layers, well known as the "Cheese" doggers, above, so called from their shape, and the "animal" or "fish" doggers below, from the frequent occurrence of vertebrate remains in them.

Inland the zone is seen and jet has been worked in various places along the northern and western escarpments of the Cleveland Hills, as well as in the valley of the Esk.

The Jet Rock is very rich in fish remains, especially the well-known "scale fish," *Lepidotus semiserratus*. The small *Leptolepis saltwicensis* may be collected from the reefs off Saltwick. Skele-

* The colour for "Jet Rock" in the Geological Maps is confined to the Jet Rock proper and so does not represent the whole of the zone of *Am. serpentinus*.

tons of saurians have also been uncovered by the Jet-workers. The ammonites are particularly numerous and interesting, the falciform ammonites being suddenly developed in a remarkable degree. There are also many specimens of belemnites, among which the curious elongated form of *Bel. tubularis*, with its flattened point, must always attract attention. There are also several species of the allied forms of the cuttle-fish type, such as *Geoteuthis*. One common fossil should also be noted, generally known as *Trigonellites*. This is of triangular form with well-marked diagonal striations, and it is generally thought to be the aptychus of an ammonite. Of the rest *Inoceramus dubius* is universal and might well mark the zone, as the best line of junction with the beds above and below is made by noting the presence or absence of that shell. In the lower part of the beds *Posidonomya bronni* is also very characteristic. The occurrence of bitumen in the shales should be noted, causing them when freshly fractured to smell strongly of that mineral, which often in liquid form fills the chambers of ammonites, and has by some been thought to be the origin of the jet, though this substance is now generally agreed to be of vegetable origin.

Among the fossils besides those mentioned above are:—*Ammonites serpentinus*, *Am. elegans*, *Am. lythensis*, *Am. exaratus*, *Am. gracilis*, *Am. heterophyllus*, *Am. cornucopia*, *Belemnites lævis*, *Bel. tripartitus*, *Bel. striolatus*, *Bel. subtennis*, *Monotis substriatus*, *Extracrinus britannicus*.

The zone of *Am. communis*, more generally known as the "Alum Shale," from its former economic value as a source of the manufacture of alum, is well exposed and easily examined both on the coast and in many of the inland valleys, owing to the large, now disused, quarries from which the shale was extracted for the purpose of the industry above mentioned. The beds first appear under the *Striatulus* beds on the scars between Blea Wyke and the Peak, and in these upper beds the fossils, such as *Trigonia literata*, are much better preserved than in the somewhat lower bed which is seen on the other side of the fault. By the time the fault is reached the beds have risen into the cliff, and on crossing it we find them some 500 ft. higher up at the Peak alum quarries a little way inland. On the other side of the anticline the Alum Shale comes down to the coast at Hawsker Bottoms, occupying the lower part of the cliffs at Saltwick and Whitby, where it is cut off by the fault. It is next met with in the Sandsend alum pits, and continues in the cliff, where not obscured by Boulder Clay, rising towards the north-west nearly as far as Old Nab, just east of Staithes; after this it is seen in the cliff of Boulby, where it has been extensively worked for alum, both on the east and west sides. After this it is seen no more in the cliffs, but like the Jet Rock it occurs along

the escarpment of the Cleveland and Hambleton Hills, and has been worked in the valley of the Esk, at Sleights and other places.

The Alum Shale consists of about 90 ft. of blue, somewhat crumbling shales, weathering white, with irregular lines of nodules in the upper part, and certain more continuous dogger bands which generally occur in the lower part. The alum quarries have been the chief repository of the large saurian remains so well known from Yorkshire. These include, besides several species of *Ichthyosaurus* and *Plesiosaurus*, the great crocodile *Teleosaurus chapmani*. Parts of the sturgeon, *Gyrosteus mirabilis*, are also met with not uncommonly, though a complete skeleton is, I believe, yet to be found. It is worthy of note that the large Liassic Reptiles of the south of England are found almost exclusively in the Lower Lias, while in Yorkshire, though occasional vertebræ and other bones are found in every zone, the complete skeletons are almost entirely confined to the Alum Shale and Jet Rock. Ammonites and belemnites are very common in the Alum Shale, as is the large *Nautilus astacoides*, but otherwise the fauna is a poor one. The structure known as "cone in cone" is not uncommon in the Alum Shale.

Besides the fossils that have been mentioned the following occur:—*Ammonites communis*, *Am. holandrei*, *Am. crassus*, *Am. subarmatus*, *Am. fibulatus*, *Am. bifrons*, *Am. heterophyllus*, *Am. ovatus* (*primordialis*), *Am. elegans*, *Belemnites vulgaris*, *Bel. veltzii*, *Bel. subaduncatus*, *Bel. subtenuis*, *Bel. dorsalis*, *Monotis substriatus*, *Gresslya donaciformis*, *Leda ovum*, *Discina reflexa*, *Lingula longovicensis*, *Eryon hartmanni*.

The zone of *Am. jurensis* occurs only between Blea Wyke point and the Peak, on the south side of the great fault there. The beds consist of a series of blue somewhat sandy shales with bands of hard, calcareous nodules at intervals. The thickness is about 80 to 90 ft., but owing to the character of the cliff in which they occur, and the occasional and imperfect exposures, it is impossible to get anything like correct measurements. The fossils may be obtained by breaking up the nodules, which are peculiarly hard. There are many species of ammonites, and belemnites are numerous and of several kinds, though rather obscure. It should be noted that the characteristic ammonite is not *jurensis* but *striatulus*, whence the beds are generally called the *Striatulus* Beds. The zonal ammonite is, however, said to occur at Blea Wyke, though I have not myself met with it.

Ammonites striatulus, *Am. compactilis*, *Am. variabilis*, *Belemnites lævis*, *Bel. subaduncatus*, *Bel. dorsalis*, *Bel. veltzii*, *Bel. latesulcatus*, *Actæonina pulla*, *Monotis substriatus*, *M. inæquivalvis*, *Trigonia literata*, and *Gresslya donaciformis* are among the fossils found in this zone.

Having now arrived at the junction of the Lias and Oolite, it will be convenient to say a few words about the Peak fault, to

which allusion has been so often made. The fault runs nearly north and south with a downthrow to the east of about 400 ft.*

The beds on the east or downthrow side (which may be called the south relatively to the place at which the fault cuts the cliff) are developed to a remarkable extent. Here we have 33 ft. of the lowest beds of the Inferior Oolite known as the Dogger, 50 ft. of passage or Blea Wyke beds, and about 80 ft. of the *Striatulus* beds, whereas on the upthrow side all these beds are absent except about 3 ft. of the Dogger, and are not again seen, though the Dogger thickens somewhat to the north, and passage beds seem again to occur in the neighbourhood of Boulby Cliff. But the fault as it now appears is of more recent date than the deposition of these passage beds, as it dislocates the whole of the overlying Estuarine series and the intercalated marine beds. At first sight, therefore, the fault can have nothing to do with the non-deposition or subsequent erosion (if deposited) of the *Striatulus* and Blea Wyke beds on the north side. It is obvious, however, that it cannot be a mere coincidence that this great change should take place exactly at this point, and that there should be a series of beds some 180 ft. thick on one side of the fault, and nothing except a poor attenuated 3 ft. of one of them on the other. There is also a change in character, as the fossils, which are so abundant on the south, though occurring mostly in certain lines, are very scarce on the north side, though farther north, between Sandsend and Kettleness, they again become numerous.

The true solution, as Hudleston† long ago pointed out, is that the movement indicated by the present fault must have taken place along an old line of fracture dating back to the closing days of the Liassic period. Some deposition and nearly contemporaneous erosion there must have been on the north side of the fault to account for the worn specimens of *Trigonia literata* and other fossils now found in the pebble bed which marks the junction of the Lias and the Dogger north of the fault. It is possible that the odd little bit of *Margaritatus* beds between the two forks of the fault on Peak Steel may be a bit left behind when the subsequent move took place, and may mark the extent of the original movement. I have given my views at greater length and reviewed the opinions of previous writers, *e.g.*, Hudleston, J. F. Blake, and Mr. Rastall, in the paper‡ I wrote for the visit of the Association in 1906, and to that paper and to the writings of the authors quoted I must refer my readers for further information.

* This figure is an average. The amount of the downthrow, or course, varies according to whether it is measured from the beds above or below the series of beds intercalated on the south side.

† *Proc. Geol. Assoc.*, vol. iii, p. 304.

‡ *Proc. Geol. Assoc.*, vol. xix, p. 419.

LOWER OOLITES.

The *Blea Wyke Beds* first occur on the scar at Blea Wyke Point about a mile south of the Peak fault. They are seen in the cliff between here and the fault, but are not met with elsewhere. As will be seen by reference to Fig. 108, the beds are divided into two distinct groups, which have been called the Grey Sands and the Yellow Sands. They rest on the *Striatulus* Beds of the Lias, but the junction unfortunately cannot be seen at Blea Wyke, owing to an accumulation of shingle, &c., filling up the little bay. It can, however, be studied in the cliff nearer Peak.

The *Grey Sands* are about 26 ft. thick, and are divided lithologically into two distinct beds, the lower of which, known as the *Lingula* Bed, is more argillaceous and softer than the one above known as the *Serpula* Bed. *Lingula beanii* occurs in both, but is particularly abundant in the lower bed, where it occurs in nodules associated with *Discina reflexa*. The upper division forms a strong scar or platform just at the foot of Blea Wyke point, and the rough surface is full of hard nests of fossils, mostly *Serpula*. There are also many belemnites in these beds and large flat ammonites of more than one species, which I should not venture to name.

The *Yellow Sands* contain scattered fossils throughout, especially belemnites and fragments of ammonites, and a fair number of gasteropods. There is a rotten band near the base full of casts of fossils, but the chief repository is a bed about a foot from the top, full of the large *Terebratula trilineata*, and known as the *Terebratula* Bed.

Ammonites aalensis, *Am. comensis*, *Belemnites bucklandi*, *Bel. aalensis*, *Bel. inornatus*, *Bel. irregularis*, *Cerithium muricatum*, *C. vetustum*, *Turritella quadrivittata*, *Monotis substriatus*, *Rhynchonella cynocephala*, *Eryma birdii*, *Serpula deplexa*, and *Vermicularia compressa* also occur.

These Blea Wyke Beds have been the subject of a good deal of controversy. Phillips* identified the Grey Sands with the Midford Sands of the South of England, and the beds above he classed with the Inferior Oolite. Wright† placed the *Terebratula* Bed and everything below in the Lias, calling it the *Opalinus*-zone. Hudleston,‡ Tate and Blake,§ the Officers of the Geological Survey,|| and all subsequent writers have drawn the line between the Oolite and the Lias at the base of the Grey Sands and at the top of the *Striatulus* Beds. Mr.

* "Geology of the Yorkshire Coast," 3rd Edition, 1875.

† "On the sub-division of the Inferior Oolite in the South of England compared with the equivalent beds of that formation on the Yorkshire Coast," by T. Wright, *Quart. Journ. Geol. Soc.*, vol. xvi, p. 1.

‡ *Proc. Geol. Assoc.*, vol. iii, p. 283.

§ "The Yorkshire Lias," chap. iv.

|| "The Geology of the Country between Whitby and Scarborough," *Mem. Geol. Surv.*, Explanation of Sheet 95 (N.W.), by C. Fox Strangways and G. Barrow.

Rastall* places the lower 25 ft. or so of the Dogger, that is to say, from the base of the *Nerinaea* Bed downwards into the Blea Wyke Beds. Personally, I should prefer to class the whole of the Yellow Sands with the Dogger, and leave the Grey Sands to be called Blea Wyke or Passage Beds, for the reason that the *Terebratulida* Bed is found at other places, and particularly near Sandsend, associated with the Dogger, and if that is placed with the Dogger the rest of the Yellow Sands must follow.

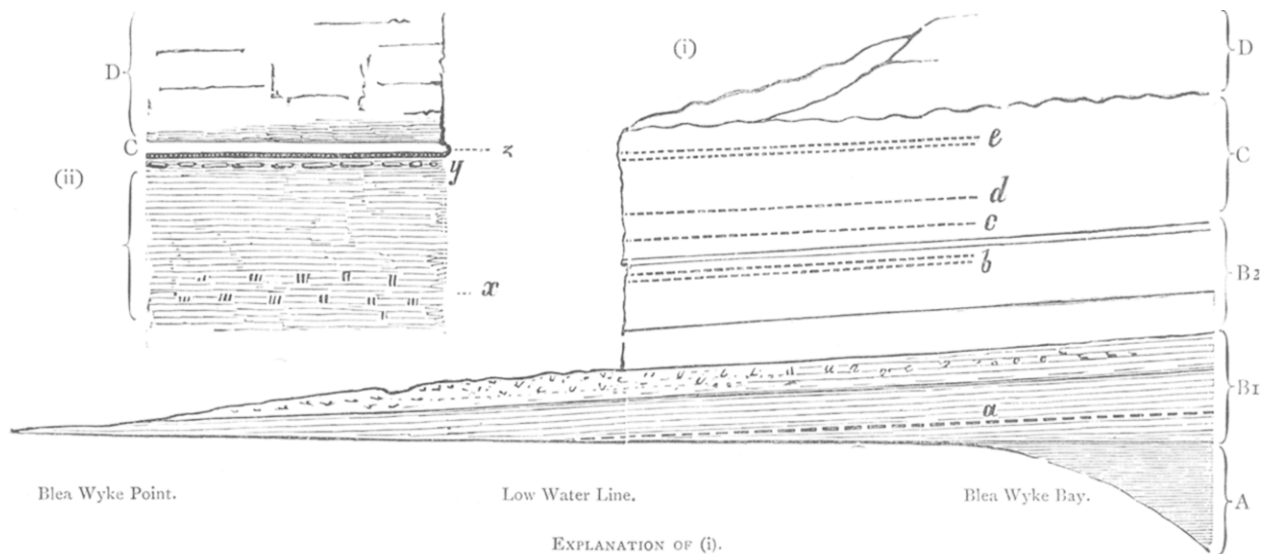
The *Dogger* at Blea Wyke consists of about 33 ft. of ferruginous sandstones of a brownish colour. In the lower part are two distinct lines of pebbles or phosphatic nodules, and about 10 ft. from the top is an extremely fossiliferous band about 1 ft. 6 ins. thick, generally called the *Nerinaea* Bed, from the abundance of the fine *Nerinaea cingenda* in it. If a good surface of this bed is exposed a collection of a great variety of fossils can be made, all in an excellent state of preservation. The Dogger reappears much attenuated in the Peak alum quarries (see Fig. 108, ii) but is not seen again in the cliff till Hawsker Bottoms is reached, north of which it continues in the face of the cliff till it comes down to the shore between Whitby and Saltwick. It then rises to be again depressed below the sea level by the Whitby fault. After the long interval of Boulder Clay the Dogger reappears overlying the Alum Shale in the Sandsend alum quarries, and continues in the cliff, or a little behind it, as far as Kettleiness, after which not much is seen of it till the lofty cliff of Boulby is reached, and at Huntcliff it reappears in the Beacon, half a mile inland, but not in the cliff itself. At Boulby it may be very easily examined in the old Loftus alum quarries on the west side of the headland, and in the Boulby quarries on the east. At the former it is very well developed and highly fossiliferous, and there is much more of the appearance of a passage from the Lias to the Oolites than in any other place along the coast except Blea Wyke.

The Dogger is seen in many inland sections, such as Glaisdale, and in some places has been worked for iron, when it is known as the "Top" Seam. In Rosedale there is a remarkable development of Magnetic Iron Ore on this horizon some 70 ft. thick, which was for some years extensively worked.

The Dogger, except where more particularly described, generally consists of a bed of ferruginous sandstone 3 or 4 ft. thick, sometimes in two blocks separated by shales. There is generally a layer of pebbles at the base of the principal block, and the junction with the Lias is usually more or less unconformable. Except at certain specified localities, the fossils are scarce and difficult to extract, the exceptions being Blea Wyke, the cliffs between Sandsend and Kettleiness, the Loftus Alum

* "The Blea Wyke Beds and the Dogger in North-East Yorkshire" by R. H. Rastall, *Quart. Journ. Geol. Soc.*, vol. lxi, p. 441.

FIG. 108.—(i) BLEA WYKE POINT SECTION. (ii) PEAK ALUM QUARRY SECTION.—W. H. Hudleston.



- EXPLANATION OF (i).
- A. *Jurensis*-zone, top part. The little bay is hollowed out of these beds.
 B. Blea Wyke Beds, consisting of: B1. Grey Sands, 26 ft.; B2. Yellow Sands, 25 ft.
 C. The Dogger, 33 ft.
 D. The Lower Estuarine Beds.
- a. Main *Lingula* Bed. b. *Terebratula* Bed. c. Lower Nodule Bed.
 d. Upper Nodule Bed. e. *Nerinea* Bed.
- EXPLANATION OF (ii), REPRESENTING CONTACT OF OOLITE AND LIAS IN PEAK ALUM QUARRY, AND SHOWING RAPID THINNING OF BEDS WITHIN HALF A MILE.
- L. Alum Shale of Upper Lias.
 x. *Leda ovum* Bed. y. Line of Clay Ironstone Nodules.
 C. Dogger, 3 ft., with x, Nodule Bed, at its base.
 D. Lower Shale and Sandstone.

Quarries, and Glaisdale inland. Among other fossils we find *Natica cincta*, *N. adducta*, *Chemnitzia lineata*, *Cerithium beanii*, *C. muricatum*, *C. vetustum*, *Nerinea cingenda*, *Alaria phillipsii*, *A. unicarinata*, *Nerita pseudocostata*, *Neritopsis levigata*, *Turbo levigatus*, *Delphinula funiculata*, *Acteon sedgwicki*, *Turritella quadrivittata*, *Pteroperna striata*, *Modiola cuneata*, *Trigonia denticulata*, *T. v-costata*, *T. spinulosa*, *Astarte elegans*, *Opis phillipsii*, *Ceromya bajociana*, *Rhynchonella obsoleta*.

The *Estuarine Beds*, or *Shales and Sandstones*, have been divided into three, Upper, Middle, and Lower. The Upper and Middle are separated by the "Grey Oolite," or Scarborough Limestone, and the Middle and Lower by the "Millepore Oolite." The Lower Shales rest on "The Dogger," and are themselves subdivided by the occurrence of a marine band to which the name of the "Ellerbeck Bed" has been given. The whole series thickens considerably as we go northwards, being quite thin in the south part of the county, and comparatively so in the region of the Howardian Hills where the marine beds are very fully developed.

The *Lower Series* is just seen at Gristhorpe below the reefs of Millepore Oolite and again in Carnelian Bay, brought up by the fault at Osgodby Nab, but does not appear again on the coast till just north of Cloughton Wyke, and it occupies the base of the cliffs from there nearly to Blea Wyke Point, when it rises in the cliff till it is cut off by the Peak fault. It reappears on the high ground inland above the Peak alum quarries, and running round Fylingdales at the back of Robin Hood's Bay it comes to the cliff again near Hawsker Bottoms, beyond which it is brought down nearly to the shore by a depression in the Lias at High Whitby, where the well-known "horsetail" *Equisetum columnare* is found upright in the sandstones as it originally grew. It then rises and continues to form the upper part of the cliff as far as Whitby, about half a mile before reaching which it is again depressed down to the shore, so that it can be easily worked for ferns, but it rises again almost immediately. By the considerable fault at Whitby, along the course of the Esk, it is thrown down so as to form the West Cliff, and is again seen forming the upper part of the cliffs at Sandsend, nearly as far as Kettlewell, and again caps the huge cliff of Boulby or Rockcliff. These Lower Estuarine Beds attain a thickness of 280 feet, and consist of shales and sandstones, with occasional seams of coal nearly six inches thick. The sandstones are much quarried for building stone, and most of the local buildings are built of it, including much of Whitby Abbey. At certain points plant remains are very abundant, and are quite equal in preservation and variety to the better known plants of the Middle Estuarine at Gristhorpe.*

* Mr. Harold Brodric has recently found at Saltwick casts in the sandstone of the footprints of some large animals.

The intercalated Marine Bed, called the *Ellerbeck Bed*, does not appear till Hayburn Wyke is reached, and may be traced thence in the cliffs as far as Peak, and can be seen at intervals wherever the Lower Estuarine Beds are visible, being near the top of the cliff at High Whitby and Boulby. It was first noted as a separate bed by Mr. Barrow,* and consists of about 15 ft. of shales and ironstones with marine shells (*Astarte*, *Gervillia*, etc.) In the Howardian district and farther south it is represented by a bed of hydraulic limestone, with *Ostrea*, etc.

The next of the Marine Beds is the *Millepore Oolite*, which forms reefs and scars off Yons Nab north of Gristhorpe Bay, overlain by ferruginous sandstones and shales with *Trigonia*, etc., which have sometimes been wrongly included in the bed above. It is then cut off by the Red Cliff fault, and is next seen brought up by a fault at Osgodby Nab between Cayton and Carnelian Bays. This is a curious section, and there are some Grey Oolite blocks mixed up with the others, but these may be boulders from the Glacial Clay. We do not see the Millepore Beds again till the north side of Cloughton Wyke, where they rise from the sea and form reefs as at Yons Nab. Past Hayburn Wyke and along the Staintondale Cliffs they may be traced till cut off by the Peak fault, and after this they are not seen in the cliff, and seem to thin out farther north, bringing the Middle and Lower Estuarine Series together. These beds have a general thickness of about 15 ft., and are noted for and named from the abundance of a bryozoa, *Cricopora* (*Millepora*) *straminea*, but there are numerous other fossils, which are not easily extracted from the peculiar ferruginous matrix. Inland the beds are more oolitic, and the fossils are obtained much more easily, as from the Whitwell Quarries in the neighbourhood of Castle Howard, where there are from 20 to 30 ft. of oolitic limestone.

The principal fossils are :—*Lima duplicata*, *Ceromya bajociana*, *Pinna cuneata*, *Modiola imbricata*, *Trigonia reticosta*, *Pygaster semisulcatus*, *Gonioseris angulata*, *Cricopora straminea*.

The *Middle Estuarine Beds* first occur at Yons Nab, and it is from this locality that most of the plants labelled "Gristhorpe" in museums have come. The beds are again seen in Cloughton Wyke, whence they continue along the face of the cliffs, getting higher and higher till, like the beds above, they run out at the Peak. These beds consist of sandstones and shales, and have a thickness of from 50 to 100 ft. They are very rich in plant remains (ferns and cycads).

The *Grey Oolite* or *Scarborough Limestone* is first seen at Gristhorpe, just above the plant bed. It is somewhat insignificant here, but has developed considerably at its next appearance

* "On a new Marine Bed in the Lower Oolites of East Yorkshire," *Geol. Mag.*, dec. 2 vol. iv (1877), p. 552.

at White Nab, the south point of Scarborough Bay, where it is about 30 ft. thick, having been depressed in the interval by the Red Cliff fault. It is not again seen till Hundale Point, south of

FIG. 109.—DIAGRAMMATIC SECTION AT RED CLIFF.—C. Fox Strangways.
[Complete Rendu Cong. Géol. Int. 1888 (1891).]



Cloughton Wyke. It there attains a considerable thickness, some 70 feet, consisting of alternations of calcareous shales, very full of fossils. It may thence be traced along the face of the Staintondale Cliffs, where it may be examined in places as far as the Peak. Large blocks have fallen from it on to the undercliff here, and the fossils may be collected. Inland it is seen in many sections, notably at Brandsby and Stonecliffe Wood in the Howardian district. From fossil evidence, notably the occurrence of *Ammonites humphriesianus* and *A. blagdeni*, it is fairly certain that this, the highest of the marine beds associated with the Estuarine series, cannot be placed higher than the Inferior Oolite of the South of England, so that, if the Bathonian period is represented here, it must be by the Upper Estuarine Beds, as has already been pointed out (see page 594).

Among the fossils besides the *Ammonites* mentioned are *Belemnites giganteus*, *Bel. quinquesulcatus*, *Cloughtonia cincta*, *Chemnitzia scarburgensis*, *Pecten lens*, *Avicula braamburiensis*, *Gervillia acuta*, *Modiola cuneata*, *Cucullæa cancellata*, *Trigonia costata*, *Myacites calceiformis*, *Gresslya peregrina*.

The *Upper Estuarine Beds* are first seen in Gristhorpe Bay, and occur again in Carnelian Bay, just south of Scarborough, and they form the cliffs, where not masked by Boulder Clay, from Scalby to Cloughton Wyke, where they leave the shore and continue to form the top of the Staintondale Cliffs nearly as far as the Peak. There is one considerable bed of sandstone known as the Moor Grit and shaly beds above with a thickness of about 100 ft. The Moor Grit has been quarried for

building stone in many places in Cleveland. There is much carbonaceous matter, but few recognisable plants, freshwater mussels being practically the only fossils.

The *Cornbrash* occurs at the top of the Estuarine Series, with which it is apparently conformable. It was formerly well seen on the north side of Scarborough Castle Hill, but not much is to be seen there now. It, however, forms a reef under Red Cliff in Cayton Bay, forming the base on which the Kellaways Rock rests (see Fig. 109). On the other side of the fault it is seen in the cliff in Gristhorpe Bay, and may be traced down to the shore a little farther south. It is a thin bed of rubbly limestone, full of fossils such as *Ammonites macrocephalus*, *Ostrea marshii*, *Avicula echinata*, *Terebratula ornithocephala*, and *Echinobrissus scutatus*.

The best exposures are met with inland in Newtondale, where it makes a kind of cliff under the platform of Kellaways Rock on each side of the Pickering and Whitby railway.

Between the Cornbrash and the Kellaways Rock are several feet of a bluish clay with *Avicula echinata*, *Glyphea*, etc., which may be classed with either formation, as they form a sort of passage bed.

THE MIDDLE OOLITES.

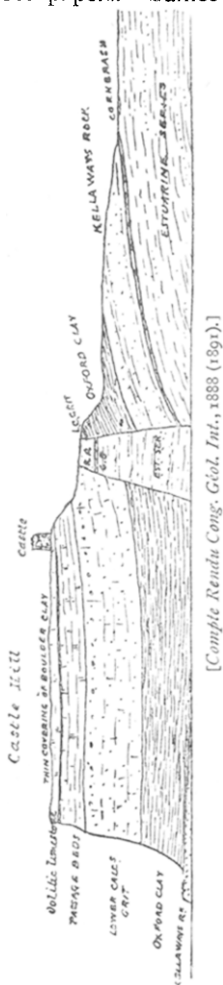
The *Kellaways Rock* is seen at Scarborough Castle, at Red Cliff in Cayton Bay, where it forms the lower part of this fine cliff (see Fig. 109), and in Gristhorpe Bay, on the other side of the fault. It is a reddish yellow ferruginous sandstone very rich in fossils. The thickness varies considerably, being some 70 feet at Scarborough, and dwindling down to less than 10 feet where it passes below the sea south of Gristhorpe Bay. Inland it is well seen in Newtondale, where it forms a sort of level platform on both sides of the valley, between the steep beds of Cornbrash and the more gently rising Oxford Clay and Calcareous Grit above. The beds have been here quarried for building stone and yield fine specimens of *Astropecten* of more than one species. Among the fossils are *Ammonites duncani*, *Am. koenigi*, *Bel. oweni*, *Alaria hispidosa*, etc.

The appearances of the *Oxford Clay* on the coast line are the same as those of the Kellaways Rock. It is a bluish grey clay about 120 feet thick. It is very well seen at Red Cliff (see Fig. 109) where it forms the middle part of the cliff, forming a slope above the steep buttresses of Kellaways Rock. Among the fossils are *Ammonites cordatus*, *Am. lamberti*, *Belemnites hastatus*, *Gryphea dilatata*, etc.

A little north of Filey the *Corallian* beds rise and run out to sea in the well-known reef of Filey Brig. This series of rocks has been so amply illustrated in the papers by the late Mr. Hudleston,

published in our PROCEEDINGS,* and by the same author and J. F. Blake in their well-known monograph in the Geological Society's Journal,† that I cannot do better than refer my readers to those papers. Suffice it to say that they divide the beds in

FIG. 110.—DIAGRAMMATIC SECTION SHOWING THE POSITION OF THE BEDS TO THE NORTH OF SCARBOROUGH.—C. Fox Strangways.



descending order into *Upper Calcareous Grit*, *Coral Rag*, *Upper Limestones*, *Middle Calcareous Grit*, *Lower Limestones* (or Passage Beds), and *Lower Calcareous Grit*. The Survey group the first four divisions as the zone of *Ammonites plicatilis* and those below as the zone of *Am. perarmatus*. The two highest divisions are not seen in the coast sections, the beds that first appear below the Boulder Clay in Filey Bay being the Upper Limestones. The Corallian Beds rise in the cliffs through Gristhorpe Bay, till in Cayton Bay they are brought down again by the fault at Red Cliff, after which they are cut off by Boulder Clay. They are seen at Scarborough Castle Rock, being brought down by a series of faults (see Fig. 110). They are not seen again on the coast, but inland they rise into the conspicuous hill of Oliver's Mount, which dominates the town of Scarborough, and stretch away to the west, forming the Tabular Hills, till they end in the great escarpment of the Hambleton Hills overlooking the Vale of Mowbray. There is a further considerable development in the Howardian Hills. There is a total thickness of upwards of 300 ft. when all the various divisions are present, though in the Howardian district the beds are thinner, being scarcely more than half that thickness.

Of the divisions of the Corallian series the *Lower Calcareous Grit* and *Lower Limestones* are well seen at Filey Brig (see Fig. 111), and again at Scarborough and the Hackness outlier. In the

* "The Yorkshire Oolites, Part II, The Middle Oolites," by W. H. Hudleston. *Proc. Geol. Assoc.*, vol. iv, p. 353, and vol. v, p. 407.

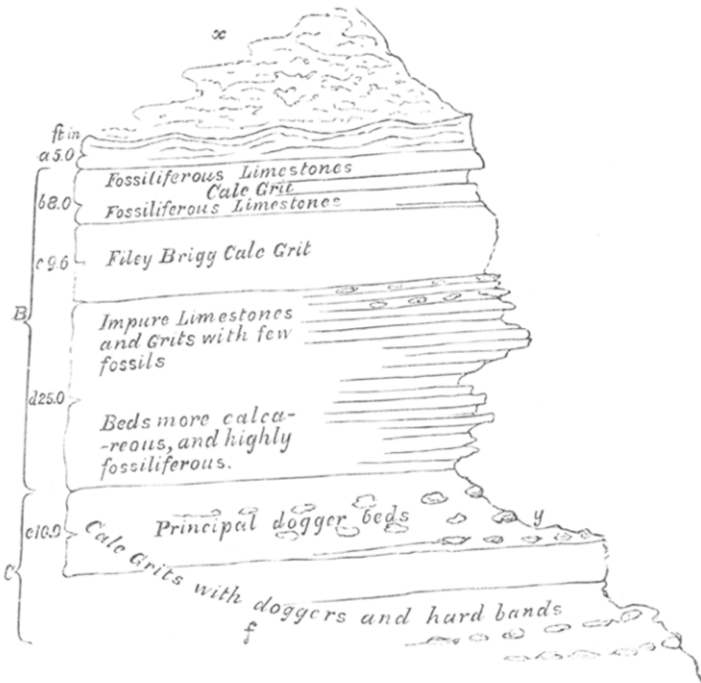
† "The Corallian Rocks of England," by Rev. J. F. Blake and W. H. Hudleston, *Quart. Journ. Geol. Soc.*, vol. xxxiii, p. 260.

latter place, and to a less degree at Scarborough, a bed of coral rag is developed in the Lower Limestones which Hudleston has called the Lower Coral Rag.

The *Middle Calcareous Grit* is best seen at Pickering, where it is very calcareous, and is remarkable for the great profusion of *Trigonia perlata*. The Filey Brig rock is a sandstone, hardly calcareous at all.

The *Upper Limestones* are well seen at Seamer, in the Hack-

FIG. III.—SECTION ACROSS PART OF THE CARR NAZE, FILEY BRIG.—
W. H. Hudleston.



x. Boulder Clay.

a and b. Upper Limestones.

c. Middle or Filey Brig Calcareous Grit.

d. Lower Limestones.

e and f. Lower Calcareous Grit.

ness outlier, and at Pickering, and are particularly well developed in the Howardian Hills at Malton and the neighbourhood, where many of the finest fossils have been obtained.

The *Coral Rag* is a very interesting phase of these beds, consisting of large reefs of coral-limestone, with brashy partings crowded with fossils, particularly spines and plates of *Cidaritis* and its allies. In the Scarborough neighbourhood it may be studied best at Ayton, Brompton, and Silpho, on the Hackness outlier.

In the Howardian Hills it is well developed at Settrington, Langton, and North Grimston, at which latter place perfect specimens of *Hemicidaris intermedia* are found, as at Calne in Wiltshire.

The *Upper Calcareous Grit* occurs at Pickering and North Grimston.

The more characteristic fossils of the Lower Calcareous Grit and Lower Limestones are : *Ammonites perarmatus*, *Am. cordatus*, *Am. vertebralis*, *Belemnites abbreviatus*, *Bel. hastatus*, *Alaria bispinosa*, *Gervillia aviculoides*, *Gryphæa dilatata*, *Pecten fibrosus*, *P. lens*, *Trigonia clavellata*, *Rhynchonella thurmanni*, *Echino-brissus scutatus*, *Millericrinus echinatus*, and *Spongia floriceps*.

In the beds above we find *Ammonites plicatilis*, *Am. vertebralis*, *Belemnites abbreviatus*, *Cerithium muricatum*, *Chemnitzia hedingtonensis*, *Littorina muricata*, *Nerinea visurgis*, *Phasianella striata*, *Gervillia aviculoides*, *Trigonia meriani*, *T. perlata*, and in the Rag *Cidaris florigemma*, *C. smithii*, *Hemicidaris intermedia*, *Pseudodiadema hemispherica*, *Isastræa explanata*, *Thamnastræa concinna*, and *Thecosmilia annularis*.

SPEETON CLAY (UPPER OOLITE AND NEOCOMIAN).

Between the Corallian and the Cretaceous Rocks there is on the coast a great series of marine clays known collectively as the Speeton Clay. The Vale of Pickering is so filled with drift that the *Kimeridge Clay* which forms its floor is only visible in occasional sections, and Filey Bay, from a little south of the Brig to Speeton, presents a long series of cliffs of Boulder Clay. About a mile north of Speeton unmistakable beds of Kimeridge Clay are very rarely to be seen on the foreshore, when laid bare by storms, and these belong to the Upper beds. They are again seen under the drift in the cliff at the north end of the Speeton section. Among the fossils are *Am. biplex*, *Am. eudoxus*, *Bel. oweni*, and *Discina latissima*. These beds form F of Mr. Lamplugh's grouping of the Speeton section (see Fig. 112).

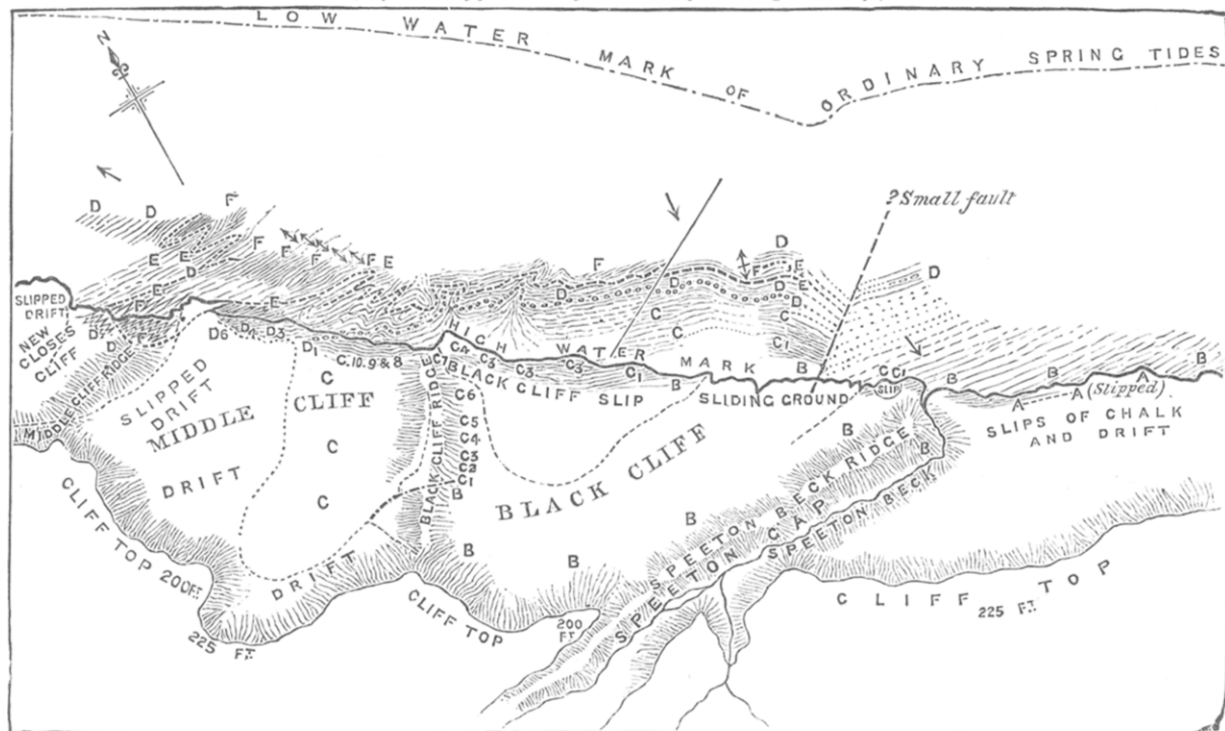
The latter was divided by Professor Judd* into an Upper, Middle and Lower Series belonging to the Neocomian, below which he placed a few feet of Portlandian represented by a bed of phosphatised nodules formerly worked for coprolites, and below that the Kimeridge Clay. Mr. Lamplugh,† however, showed that there were two beds of nodules some 35 ft. apart (see Fig. 112). The upper of these, consisting of large limestone and smaller phosphatised nodules, he called the "Compound Nodular Bed"; the lower, consisting of phosphatised nodules, he called the "Coprolite Bed." The last-named bed he grouped as E, while

* "On the Speeton Clays," *Quart. Journ. Geol. Soc.*, vol. xxiv, p. 218.

† "On the Sub-divisions of the Speeton Clay," *Quart. Journ. Geol. Soc.*, vol. xlv, p. 575.

FIG. 112.—SKETCH-MAP OF THE COAST AT SPEETON, SHOWING THE COURSE OF THE BEDS ON THE SHORE AND IN THE FOOT OF THE CLIFF.—G. W. Lamplugh.

(Reproduced by permission of the Council of the Geological Society.)



A. Marly clays, with *B. minimus*, etc. (slipped).

B. Clays of zone of *B. brunsvicensis*.

C. Clays of zone of *B. jaculum*.

D. Clays of zone of *B. lateralis*.

oooo Compound Nodular Bed (D).

E. Coprolite Bed - - - - -

F. Bituminous Shales with *B. oweni* and vars.

(The lines show the strike; where continuous, the beds have been actually observed; where broken, they are as supposed). Scale; 9 inches = 1 mile.

the beds above up to and including the Compound Nodular Bed he classed as D, or the zone of *Belemnites lateralis*. From a careful consideration of the fossils he came to the conclusion that the whole of the groups D and E belong to the Portlandian, a view in which he is supported by Professor Pavlow, thus taking the limits of the Oolite higher up than previous geologists, though the non-recognition of the fact that there were two nodular beds makes it very doubtful where various workers really drew their lines.

The next 100 feet or so of the clays Mr. Lamplugh classes as C, or the zone of *Bel. jaculum*, and this includes practically the whole of the Middle and Lower beds of Prof. Judd. These beds are full of fossils, especially *Crioceras* and many species of ammonites, *Bel. jaculum*, *Pecten cinctus*, *Toxaster complanatus*, *Meyeria ornata*, etc. Above these are about the same thickness of clays which Mr. Lamplugh calls B, or the zone of *Bel. brunsvicensis* (*semicanaliculatus*). They represent the Upper Division of Prof. Judd. Fossils are not so common, but there are many specimens of *Crioceras*, also *Am. deshayesii*, *Vermicularia sowerbyi*, etc. Mr. Lamplugh considers that these beds represent the Atherfield Clay of the south of England. Above are a few feet of clay of a passage character, Mr. Lamplugh's A, or zone of *Bel. minimus*, which are overlain according to that observer, conformably by the Red Chalk, though other geologists have considered that there is here a break in the succession.

It is a curious thing about the Speeton Clay that it is hardly to be traced at all inland, the only occurrence of any importance being at Knapton, where it was formerly worked for coprolites. If it exists farther inland it is hidden under the overlap of the Chalk, and is not seen again in Yorkshire, though the corresponding beds in Lincolnshire are well known and are described in the article on that county. (See Chapter XXI, p. 502.)

CRETACEOUS BEDS.

The *Red Chalk* which appears just under the white cliffs of Speeton has generally been correlated with the similar beds at Hunstanton and with the *Gault* of the south of England. It contains *Bel. minimus* and other fossils, and the main mass is about 30 feet thick. There are other red bands higher up, but they belong to the Lower Chalk.

The *Lower Chalk* has been well described by Mr. W. Hill.* He says that at Speeton there is a total thickness of about 120 feet, and he has established the existence of the following beds in descending order : *Actinocamax plenus* marls, Grey Chalk,

* "On the Lower Beds of the Upper Cretaceous Series in Lincolnshire and Yorkshire," *Quart. Journ. Geol. Soc.*, vol. xlii, p. 320.

Grey Bed or Totternhoe Stone, and Chalk Marl. The highest red band is some 80 feet above the true Red Chalk.

The *Upper* and *Middle Chalk* have recently formed the subject of one of the series of monographs by Dr. Rowe, on the Coast Sections of the Chalk throughout England,* which have appeared in our PROCEEDINGS. He has treated the subject in such an exhaustive fashion that it is not necessary to say more than that he has established the following zones in descending order: *Actinocamax quadratus*, *Marsupites testudinarius* (with *Uintacrinus*-band), *Micraster cor-angulum*, *Micraster cor-testudinarium*, *Holaster planus*, *Terebratulina gracilis*, and *Rhynchonella cuvieri*. The total thickness is about 1,200 feet. It is a curious fact that the upper part from about the middle of the zone of *Micraster cor-angulum* is without flints, while the chalk below from the zone of *Terebratulina gracilis* is characterised by regular lines of flints, just the reverse of the south of England. Hence previous writers have been content to classify the Chalk of Yorkshire as an Upper Division without flints, and a Lower Division with flints.

GLACIAL BEDS.

These were first divided by S. V. Wood and Rome† into Hesse Clay, Purple Clay, and Basement Clay, and subsequently by Mr. Lamplugh‡ into an Upper and Lower Boulder Clay, with an intermediate bed of stratified clays, sands, and gravels.

There is hardly a bay along the coast in which the glacial beds are not seen. As has been already mentioned at the beginning of this paper, the whole coast south of Flamborough, known as Bridlington Bay, is composed of glacial beds. We find them also in Filey, Cayton, and Scarborough (north and south) Bays, the bays north of Scalby, Robin Hood's Bay, Dunsley Bay to the west of Whitby, Runswick Bay, the bay between Staithes and Boulby, Skinningrove, and Marske Bay, and they cover considerable tracts inland. They consist of red and brown, very tough clays, full of boulders of all sorts and sizes, often well polished and with well-marked striæ, and intercalated layers of sand and gravel. The cliffs often weather into curious craggy forms owing to the furrowing of the rain-water on their bare surfaces, as may be seen in Filey Bay. The boulders vary from the great masses of Lias in Filey Bay to the smallest stones. Instances of striated rock surfaces preserved under these clays are rare. One was

* "The Zones of the White Chalk of the English Coast, Part iv, Yorkshire," *Proc. Geol. Assoc.*, vol. xviii, p. 193.

† "On the Glacial and Post-glacial Structure of Lincolnshire and South-east Yorkshire," *Quart. Journ. Geol. Soc.*, vol. xxiv, p. 146.

‡ "On the Drifts of Flamborough Head," *Quart. Journ. Geol. Soc.*, vol. xlvii, p. 384.

noticed by Mr. Lamplugh* on the surface of the Upper Limestone near Filey Point, in which the direction of the striæ was north 20 deg. east.

A study of the boulders will soon convince anyone that the movement was from the north. The great masses of Lias are mostly found in Filey Bay, south of the outcrop of these beds. Farther north we find blocks of Permian or Carboniferous Limestone. There are also a number of igneous rocks, amongst others the easily recognisable Shap granite. A careful record of the boulders has lately been compiled by the Yorkshire geologists.† It is generally supposed that the glacier or ice-sheet descended the valley of the Tees from the west, and then turned south along the coast, finding its way into all the old valleys as it advanced and plugging them up. It is considered by some geologists that it was forced to do this by being met by a stronger sheet advancing from Scandinavia, though this opinion is not unanimous. Whatever the cause, the result has brought about the peculiar circumstance which I have already mentioned, namely, the practical absence of rivers all along the Yorkshire coast. Even the one exception, the Esk, has had to cut itself a gorge to escape out to sea, its natural outlet into Dunsley Bay having been blocked by the Boulder Clay. The drainage of a large area both of the Moors and the Tabular Hills, the waters of which now join the Derwent and escape through the gorge at Kirkham Abbey to flow southwards into the Ouse, would naturally have flowed the other way down the Vale of Pickering into the sea in Filey Bay. The great mass of clay which was forced into Filey Bay had the curious effect of turning the river back on its course, and it probably created a lake the waters of which escaped by the channel of least elevation. In the same way the upper Derwent, which would have flowed into the sea at Scalby, was forced to cut through the Forge Valley gorge into the Vale of Pickering (see page 594).

Prof. P. F. Kendall‡ has recently written an extremely interesting and suggestive paper on a system of lakes which he believes to have existed in glacial times in the valleys of the Cleveland Hills, caused by the damming up of the waters by the ice filling the valleys. It is too long a subject to treat of in this article, and it can only be properly understood by carefully following the evidence on the ground, if possible, with Prof. Kendall as a guide.

The occurrence of an old pre-glacial chalk cliff and beach at

* "On the larger Boulders of Flamborough Head and other parts of the Yorkshire Coast," by G. W. Lamplugh, *Proc. Yorks. Geol. and Poly. Soc.*, vol. xi. p. 401. Prof. Kendall on p. 494 of his paper cited below mentions five other cases of striation.

† Reports of East Riding Boulder Committee in the "Transactions" of the Hull Geological Society.

‡ "A System of Glacier Lakes in the Cleveland Hills," *Quart. Journ. Geol. Soc.*, vol. lviii, p. 471.

Sewerby, north of Bridlington, described by Mr. Lamplugh,* should be noted; also the deposit at Speeton with marine shells (*Littorina*, *Cardium*, etc.), which is apparently an inclusion of contemporaneous date in the glacial clays. The same applies to the so-called "Bridlington Crag," formerly to be seen at that place, and probably also to the *raised beach* at Saltburn. The bottoms of the old pre-glacial valleys are now somewhat below the present sea-level, indicating that the land has been depressed since that time.

For further particulars I must refer the reader to the papers by Mr. Lamplugh and Prof. Kendall already quoted, and to the instructive address delivered to Section C of the British Association by the former, at the York meeting in 1906, in which he reviews the evidence for and against "inter-glacial" periods.

CAVE DEPOSITS.

No description of the district would be complete without a mention of the well-known Kirkdale Cave and its mammalian remains described by Buckland. The cave was found in a quarry of Corallian limestone at Kirkdale, near Kirby Moorside. It had evidently been a hyæna's den, from the gnawed condition of the bones found.

IGNEOUS ROCKS.

Besides the boulders contained in the glacial deposits, the only igneous rock in the district is the great Cleveland Basaltic Dyke, which traverses the country for miles in a nearly straight line with a direction almost west-north-west and east-south-east from the Tees valley to the moors at the back of Robin Hood's Bay. It is largely quarried for road metal, locally called Whinstone, in the neighbourhood of Goathland and Egton Bridge. It is newer than the Lower Oolites through which it cuts, and is probably of Tertiary age.

* *Quart. Journ. Geol. Soc.*, vol. xlvii, p. 394.