

28. *THE EOCENE DEPOSITS OF DORSET.* By CLEMENT REID, Esq., F.L.S., F.G.S. (Communicated by permission of the Director-General of H.M. Geological Survey. Read April 29th, 1896.)

THE new survey of the western end of the Hampshire Basin having necessitated certain modifications in the geological map, it may be useful to lay the principal results before the Society. If the alterations were mere matters of detail, this would scarcely be worth while; but the more accurate mapping has led to the discovery of a sudden westerly change in the character of the Lower Bagshot Sands, and of a well-marked overlap at their base. The mapping of the Tertiary strata proves also that there is evidence of other periods of earth-movement in southern England, besides those already known,¹ and that we are dealing with one of those regions where folding affects the same area again and again.

When the Eocene strata are followed westward through Sussex and Hampshire into Dorset, one finds constant local changes in the lithological character of the deposits, though these changes seem all to tend in the same direction. Marine beds become less conspicuous, coarser, more estuarine, and estuarine deposits become truly fluviatile. Thus the London Clay, which exceeds 300 feet in thickness to the east, dwindles to less than 100 feet in Dorset, and becomes more sandy and pebbly, though still apparently of marine origin. The Woolwich and Reading Series—fluvio-marine at Newhaven and Portslade, and slightly so at Lancing—becomes more fluviatile westward, lenticular patches of subangular gravel appearing in it west of Wareham. To what extent the Reading Series rests unconformably upon the Chalk is difficult to say, though overlap is clearly recognizable in various places. The Lower Bagshot Sands also become coarser and more purely fluviatile westward, the change being a singularly rapid one in the neighbourhood of Dorchester. It is to this change in the Bagshot Sands, and the conclusions to which it leads, that attention will more especially be drawn in the following notes.

1. Woolwich and Reading Series.

The extreme variability of these deposits makes it difficult, till a large area has been examined, to master any general tendency in the variations. No particular bed seems ever to be traceable more than a short distance, the whole series being made up of a succession of alternating masses of red-mottled clay, loam, sand, and gravel. Plant-beds and marine strata alternate at Newhaven. At Brighton and Portslade the deposits are still of the Woolwich or fluvio-marine

¹ See Reid, 'Pliocene Deposits of North-western Europe,' *Nature*, vol. xxxiv. (1886) p. 341; Reid & Strahan, *Mem. Geol. Surv.* 'Geology of the Isle of Wight,' 2nd ed. 1889, chap. xiv.; Reid, 'Pliocene Deposits of Britain' *Mem. Geol. Surv.* 1890, pp. 69, 70; Strahan, 'On Overthrusts of Tertiary Date in Dorset,' *Quart. Journ. Geol. Soc.* vol. li. (1895) p. 549.

type. At Lancing the strata are mainly of the Reading type, consisting of alternations of red-mottled clay, loam, lignite, and sand; but even there certain ironstone-nodules near the base yield casts of marine shells. From Worthing westward the southern margin of the Hampshire Basin yields no evidence of marine conditions.

An increasing rarity of marine fossils is not the only change that takes place when the Woolwich and Reading Series is traced westward, for directly we pass from Hampshire into Dorset it is noticeable that the sands are often coarse and full of small splinters of flint. A few miles farther west, at Morden and at East Lulworth, lenticular masses of coarse subangular gravel make their appearance in the Reading Beds, and these gravels, especially at Morden, contain a considerable percentage of Greensand chert with sponge-spicules. This admixture of coarse sand and subangular gravel becomes still more marked towards the western limits of the formation, and the proportion of Greensand chert increases.

2. London Clay.

Though the London Clay thins and becomes more sandy to the west, there is no sign of shore or estuarine conditions, and even at its western limit it is apparently of purely marine origin. The flint-pebbles at the base of the formation are all perfectly rounded, as in other localities, and do not yield any evidence of beaches. The only fossil that I have seen from the London Clay in Dorset is an indeterminate bivalve, apparently a *Cyprina* or *Cytherea*, obtained from the basement-bed in a boring at Wimborne. This absence of fossils is, however, in all probability due to the sandy pervious nature of the deposit; for though more typical London Clay with septarian ironstone-nodules occurs, sections in unweathered material are very scarce. Throughout the Hampshire Basin the London Clay seems always to rest, with a sharp, slightly eroded junction, on the Reading Series; yet there is no trace of either unconformity or overlap, the thickness of the Reading Beds remaining approximately the same throughout.

3. Lower Bagshot Beds.

The changes undergone by the Bagshot Sands are even more marked than those that take place in the Lower Eocene strata. If we follow the southern margin of the Hampshire Basin we discover that the Sands are thin and scarcely recognizable in the Selsey Peninsula. In the Isle of Wight, however, they expand enormously, reaching 150 feet at the eastern end of the island and 600 feet at the western, where they contain lenticular masses of white pipe-clay with plant-remains. The Bournemouth cliffs show a tendency to the increase of coarse sands, containing small fragments of black grit, lydite (or radiolarian chert), and occasionally of Greensand chert; splinters of flint also begin to appear. Coarse sands of this character continue to be associated with the pipe-clays westward to beyond Wareham. Then sets in a change like that

undergone by the Reading Beds, but far more marked. The Bagshot Sands become coarser and gravelly, unworn flints and flint-splinters become abundant, and mixed with these is found a quantity of subangular Greensand chert, like that occurring in the Reading Beds. There is, however, one character which enables us easily to distinguish between the Bagshot and Reading gravels. The Reading gravels consist of flint and chert, with an occasional quartz-pebble: careful search yielding nothing else except one or two small quartzite and grit-pebbles. Bagshot gravels, on the other hand, contain, besides flint and chert, so much quartz and hard subangular Palæozoic rocks as to make the finer screened material look like a Cornish beach. They yield also a certain quantity of Purbeck marble and other Purbeck rocks, though I have been unable to discover any trace of Portland Beds or of the Oolites below.¹

This gravelly condition of the Bagshot Series first becomes conspicuous in the large pits close to Moreton railway-station, where 40 feet or so of the sands can be seen associated with seams of white pipe-clay. In this pit one can find fragments of all the rocks which occur in the coarser gravels farther west. It is noticeable also that the chert-fragments found in the lower part of the pit are often quite soft, so that they were at first mistaken for pebbles of pipe-clay, though they soon harden on exposure to the air. A softening of the chert-pebbles will explain the curious way in which the fragments are sometimes dented by each other and pitted by sand-grains, at a locality where neither earth-movement nor pressure has ever been extreme. As I found rounded quartz-grains half embedded in some of the flints it is possible that Chalk-flints also can to some extent be softened in a similar way.

To the west of Moreton the Bagshot gravels rapidly become much coarser, and as they change the Bagshot Series cuts through the London Clay and through the Reading Beds, till it rests immediately on the Chalk. The various outliers south and south-west of Dorchester all belong to the Bagshot Series, not to the Reading Beds as formerly supposed.

A study of the composition of the Eocene gravels shows distinctly that the rivers that brought them must have flowed from the west or south-west. Both Reading and Bagshot gravels become coarser and the stones more angular in that direction, and seem to occupy a valley eroded in the Secondary strata. But of the extent of this erosion it is difficult to obtain direct evidence, for the wide trough south-west of Dorchester, in which several of the Eocene outliers lie, is mainly a continuation of the syncline of the Hampshire Basin, not an eroded hollow. A considerable amount of erosion of the Chalk seems to have taken place before the Ridgeway and Blackdown (Hardy's Monument) outliers were deposited; but I am quite

¹ Some of these rocks are recorded by Sir Joseph Prestwich as occurring at Blackdown in gravel, which 'may belong to some part of the Glacial period,' overlying the Eocene beds. The gravels seem to me to be of Eocene age. See Quart. Journ. Geol. Soc. vol. xxxi. (1875) p. 41.

unable yet to say to what extent the position of these outliers is due to erosion as distinguished from folding. The Rev. O. Fisher states¹ that when the large ballast-pit on Bincombe Down was open during the making of the Ridgeway cutting, the Tertiary strata were seen to be vertical. Sir Joseph Prestwich² and Mr. Strahan,³ however, in their sections, draw the Eocene base as markedly unconformable on the upturned Chalk. All that can now be clearly made out is that in certain parts of the old ballast-pit the Eocene strata are highly inclined. It is, however, so extremely difficult to obtain accurate dips in these deposits, owing to the occurrence of piping on a scale which I have never seen equalled, that it is unsafe in the present state of the section to express any confident opinion as to the exact relation of the Bagshot strata to the Ridgeway disturbance.

Though it may be impossible readily to prove by stratigraphical evidence the overlap of the Lower Bagshot Beds, yet the composition of the gravels demonstrates unmistakably this discordance. One finds on analysis that the gravels contain in the first place abundance of Chalk-flints. Next in abundance come numerous fragments of the Greensand chert already mentioned. The pieces are usually subangular, and of all sizes up to a foot in diameter; so they are not likely to have travelled far. The chert is probably derived from the Upper Greensand.⁴ Numerous pebbles of vein-quartz, mostly under an inch in diameter, next attract one's attention, and it is not improbable that these may come from conglomeratic seams in the Wealden strata of the immediate neighbourhood. Fragments of Purbeck marble, sometimes silicified, are fairly common, and are associated with cherts and grits probably also of Purbeck age. All the rest of the material consists of subangular veined grits, hard sandstones, quartzites, quartz, radiolarian chert, and red and green jaspers; in fact, of hard siliceous material such as might be derived from the weathering of the Permian breccias of Devon. Black grit with small quartz-veins is abundant, and, like the radiolarian chert, suggests the Culm Measures as its source, though probably it also is derived secondarily through the Permian breccias. Budleigh Salterton Triassic pebbles are, however, entirely missing.

This peculiar composition of the gravels ought to give us a clue to the amount of denudation that had then taken place, and also to the direction in which the river flowed. The gravels of the Reading Series, containing Chalk-flints and Greensand chert, suggest that erosion at that period had only reached down to the Upper Greensand; though even this amount of erosion points to a distinct post-Cretaceous upheaval in the neighbourhood, which tilted the Chalk and brought Greensand within reach of the eroding agent, before the deposition of the Reading Beds.

During, or before, the Bagshot period there seems to have occurred another era of local disturbance, during which both

¹ *In lit.* [since published in *Geol. Mag.* for June 1896].

² *Quart. Journ. Geol. Soc.* vol. **xxi.** (1875) pl. i. fig. 2.

³ *Ibid.* vol. **li.** (1895) pl. xviii.

⁴ [Chert of identical character has since been found in the Upper Greensand near Abbotsbury.—July, 1896.]

Reading Beds and London Clay near Dorchester were so tilted as to lead to a sharp transgression of the overlying Bagshot gravels. It happens thus that within a distance of 3 miles the Bagshot gravels cut through both those formations. A short distance farther west, at Bincombe Down, the gravel has cut well into the Chalk, and there is little doubt that within a few miles it must have overlapped all the Cretaceous rocks and cut into Purbeck Beds. The reason why it is suggested that the Purbeck stones can only have come a short distance will be seen on looking at a geological map. Purbeck rocks might be obtained in the immediate neighbourhood of the Bagshot gravels, on the south side of the Bincombe fault; but they could not have been derived from regions farther west, as in that direction the Purbeck Beds had already been denuded and overlapped by the Greensand. This overlap becomes more pronounced westward, the Greensand resting unconformably on all the Secondary rocks, till at Haldon there is nothing between the Greensand and the Permian breccias. It thus comes about that no Jurassic fragments are found in the Bagshot gravels, with the exception of Purbeck rocks, which seem to have bordered the southern edge of the Eocene valley. The rest of the gravel was apparently derived from the higher part of the river-basin, where Greensand rests directly on Permian strata, even the Budleigh Salterton pebble-bed being overlapped and hidden.

It is noteworthy that the new evidence discovered in the western end of the Hampshire Basin strongly supports the idea that the pipe-clays of the Bagshot Series are derived from the weathering of the Dartmoor Granite, and that the Bovey Tracey outlier, so like the deposits around Bournemouth, is, as maintained by Mr. Starkie Gardner, of the same age and deposited in the same basin, though in Devon Eocene rest directly on Palæozoic rocks. Bovey Tracey is only a short distance from Haldon, and Permian breccias, Culm Measures, and granite rise into hills in the immediate neighbourhood. That district might have provided the whole of the material in the Bagshot gravels, with the exception of the Purbeck marble.

A consideration of the evidence now brought forward shows that besides the already-recognized earth-movements of intra-Cretaceous, early Eocene, Miocene, and Pliocene dates, there must have been folding during at least one other period in the same or closely adjoining areas. The earliest, or intra-Cretaceous, folding accounts for the marked unconformity of the Upper Cretaceous on all the older rocks. The second disturbance, either late Cretaceous or early Eocene, during which the Bincombe overthrust must have commenced, caused Reading Beds to overlap the Chalk and rest on Upper Greensand. A third disturbance allowed Bagshot Beds to cut across the upturned edges of the London Clay, Reading Beds, Chalk, and Greensand and reach the Purbeck and older rocks. Finally we have the well-known Miocene folding, which threw the whole of the Tertiaries of the Hampshire Basin into a series of sharp undulations with an east-and-west axis, and this movement

seems to have continued till early Pliocene times. It would thus appear that the district between Dorchester and Weymouth is one of those areas of weakness which are affected again and again by similar disturbances.

The discovery of the peculiar composition of the Eocene gravels of Dorset has thrown an unexpected light on the source of the material in the Pleistocene series. These gravels, from Brighton westward into Dorset, always contain a considerable proportion of Greensand chert of marked character, besides other foreign stones. Of these stones a considerable number have been shown to be glacial erratics brought by floating ice, though the glacial erratics are entirely confined to low levels and to the area between Brighton and Southampton Water.¹ Above that level and beyond that district the Plateau-gravels contain, however, large quantities of chert and also of Palæozoic grits and quartz. The cherts have usually been considered to point to derivation from a central Wealden axis. But when it is found that the masses become larger and more abundant westward, and that they are always associated with Palæozoic grits that could not be derived from the Wealden area, it is evident that they can have no connexion with the Weald, but clearly must have been derived from Devon and Dorset. Every kind of rock found in the Plateau-gravels of Sussex, Hampshire, and Dorset above the level of the glacial action has now been traced to the Bagshot gravels of Dorset, and through them to districts still farther west.

DISCUSSION.

Mr. STRAHAN said that he had had occasion to trace part of the Tertiary base-line while mapping the Secondary rocks in South Dorset, and that he had speculated on the age of the gravel-outliers near Dorchester. No clue, however, was forthcoming until the Tertiary deposits were mapped by Mr. Reid from Hampshire continuously westwards, and the overlap of the Bagshot Beds traced step by step. It had seemed to him that there was a marked discordance in the extreme west between the Eocene and Cretaceous; in fact, the Chalk seemed to have been carved into hill and dale before it was overspread by the Eocene. Moreover, in drawing a section through Bincombe, he had found that there was not room for the whole of the Chalk below the Tertiary outlier, and had been obliged to show a marked overlap by the latter, as had been previously done by Sir Joseph Prestwich. The Author's observations tended to confirm this conclusion. He considered that the Author had made a material advance towards solving an important problem in Tertiary geology.

Mr. MONCKTON remarked that if pebbles from the Permian of the West of England were found in the gravels described by the Author, it was rather surprising that the liver-coloured quartzites of the Triassic pebble-beds should not also occur. He asked whether there

¹ See Quart. Journ. Geol. Soc. vol. xlviii. (1892) p. 344.

was evidence founded on superposition of strata in well-sections or otherwise to show that the gravels are really of Reading or Bagshot age.

Mr. H. B. WOODWARD considered that the Author had proved his contention with regard to the composition of the Bagshot gravels. He had seen the gravel on Blackdown (Portisham), and, having found blocks of greywether in it, he had taken it for Drift. He was now prepared to believe anything ; but he would ask the Author to state how he distinguished between the outliers of Bagshot gravel and those of Drift gravel, as the question of the overlap of the Bagshot Beds depended greatly thereon.

Mr. R. S. HERRIES said that there were several points of interest in this paper, such as the continued thinning of the London Clay towards the west, and the remarkable persistence in the thickness of the Reading Beds in spite of their changed character. The evidence of the Reading or Bagshot age of the gravels did not seem quite conclusive, and it might turn out that they were later still. The conclusion that the materials of which they and the later gravels are composed were derived from the west was most interesting, and there seemed every reason to suppose that it was correct.

Dr. G. J. HINDE also spoke, and the AUTHOR replied.