

VI.—OBSERVATIONS ON EAST ANGLIAN BOULDER-CLAY.

By the Rev. E. HILL, F.G.S.¹

I DESCRIBE some facts which have attracted my attention in my neighbourhood as bearing on the question of the East Anglian Boulder-clays, and I note the directions in which these facts would seem to lead our ideas. For the most part I limit myself to my own observations.

The soil of my neighbourhood is extremely heavy. Boulder-clay is the subsoil, and is often turned up by the plough. The great lumps and clods are dried by the sun into masses almost as hard as brick. But these iron clods, penetrated by the frosts of the severe winters we have lately had, become such that, after the frost has passed away, at the tap of a stick they crumble into a fine powder and almost into dust. If such be the effect of present winters, what may not have been within the power of winters in the great Ice Age. It should be noted also that the matrix of the East Anglian Boulder-clay seems chiefly Kimmeridge clay, while that of the Midlands is, I believe, chiefly Keuper and Lias. These are clays which frost would pulverize, and which occur in the respective regions. There is, then, no need to call in a glacier grinding-mill to make a matrix for the Boulder-clay. These observations seem to point to the land-ice theory being unnecessary.

In the matrix of clay, besides flints, there lie pieces of chalk of every size, from boulders measured by yards down to the pea and the pin's head. I find it difficult to understand how a glacier could grind chalk to anything other than powder. But frost makes the face of a clunch wall or chalk quarry scale off, and showers down pieces of every size. The number of these pieces in the clay is great. I have tried to count the number in a definite area. Counting only pieces of pea size and upwards, I have twice found as many as ninety to the square foot. How come these to be so intimately mingled with the clay-matrix.

Again, how are the clay and chalk brought together at all? The Kimmeridge clay all lies far to the west of Suffolk; I know of none nearer than Ely. On the other hand, chalk occurs as a constituent of Boulder-clays in the Midlands far to the west of all Cretaceous beds. Chalk, then, has been carried westwards, and clay in the opposite direction. What was the agent which could carry east and west at once? Certainly not those glaciers whose course can be mapped by their contents. These observations seem to indicate that the land-ice theory is impossible.

In digging wells many blocks of chalk and limestone brought up are found to be striated or scratched. One such (which was shown), from a well at Felsham, is scratched on one side only; the other side is a mass of fossils, unscratched. It may be a split portion of a larger block, or it may have had one side protected by ice. But in any case clearly it was scratched first and placed in the clay

¹ A paper read at the Ipswich Meeting of the British Association.

afterwards. If the stone and the clay were deposited together, and deposited by water, the appearance is intelligible. The natural explanation is that the Boulder-clay was deposited in water, and that ice, floating over this water, carried stones and dropped them.

The clay is found in West Suffolk up to heights of 340 feet; but none of the neighbouring outcrops of chalk reach 300 feet. I have attempted to trace the contour-line of 300 feet from the Tees to the Thames. The tracing shows that chalky Boulder-clay in East Anglia attains a higher level than any ground northwards up to the Lincolnshire Wolds. Even there, the elevated area of chalk is smaller than the equally elevated area of East Anglian clay. Besides, Mr. Deeley tells us that chalk-drift is found in Leicestershire up to 800 feet, which is far higher than any Northern chalk. It seems, therefore, natural to suppose that much chalk country was then relatively higher than now; accordingly that a tilt of the surface has taken place since Glacial times.¹ This is similar to a conclusion which Prof. Prestwich arrived at, on the independent evidence of his Westleton beds.

Another observation of mine may have a significance. In some brickyards a coarse clay is ground up with water and allowed to settle in shallow pits. A similar material is produced in Cambridge-shire when the mud, washed off from coprolites, has been run into the 'slurries.' When I have seen these pits cut into, their material in its texture has sometimes strongly recalled to me some of the finer varieties of Boulder-clay—for instance, the chocolate-coloured clay of Holderness. This likeness suggests that the deposition of Boulder-clay was a process which went on rapidly. If so, the formation may have taken place in less time than we are accustomed to suppose.

The above observations, then, taken together, suggest the picture of a broad sheet of water surrounded by slopes of clay and scarps of chalk. These are to be broken and pulverized by winter-frosts, and washed down in muddy torrents by spring or summer rains, while stones embedded in ice are also carried down, scratched in the transit, and floated far before they are dropped. But the surface of these waters cannot be still, nor even flowing in a uniform direction. There must be tides, eddies, or varying winds, since something seems required to drift the ice-rafts across the movement of the muddy waters, so as to produce the mixture of materials which we find.

I have confined myself to my own area and my own observations; also I have made no attempt to answer the difficulties which may be raised. There are, however, two obvious objections on which something may be said. It is urged that if the Boulder-clay be of aqueous origin, it ought to contain fossils and be stratified. If my

¹ This argument of course assumes the conclusions previously arrived at. Those who maintain glacier-transport should bear in mind that, unless levels have changed, the ice must have been at a yet higher level above the spot whence it brought the chalk. If this came, for instance, from Speeton, Flamborough Head must then have been buried beneath 500 feet of ice.

suggestion that it was formed rapidly have any truth, fossils need not be expected. Thick muddy waters would probably be quite unfitted for life. I do not think there are fish in the muddy Swiss glacial streams.¹ And the artificial clays I have described sometimes show little or no stratification on a small scale. On a large scale the Boulder-clay is stratified. I have seldom gone far without finding traces of this. Often, indeed, it is as clearly stratified as any other clay.

There are doubtless many other difficulties, some of which may be fatal. I offer this paper as an independent contribution to a most controverted, and therefore most attractive, question.

VII.—BRITISH GEOLOGY IN RELATION TO EARTH-FOLDING AND FAULTING.²

By T. MELLARD READE, C.E., F.G.S., F.R.I.B.A.

THE history of every science may be compared to the ascent of lofty and diversified mountains, in which level benches and plateaux alternate with steep and rugged slopes. The first explorers, beginning at the base, toil upwards, hardly knowing which course to take, and having little idea of the country that lies before and above them. But they toil on, gathering information as they go, until, reaching a level resting-place, they can look back and form a more accurate conception of the country they have traversed. Still, they can see but a little way upwards, much less perceive the summit, but ascend they must, gaining an ever-widening view and grander and more just conceptions of the wide world below.

It is thus that the study of geology has progressed. By the combined operation of an army of explorers a vantage-ground has been obtained from which we are enabled to review our position and determine upon the next point of attack.

The history and succession of the rocks have been traced, their position in time and in part, their location in space—but the latter knowledge can never be complete until the whole world has been surveyed, both above and below the waters; now a seemingly impossible task: yet who shall speak for the future?

By the aid of numerous geologists, both great and humble, of all climes and countries, manfully working towards a common end, the order of succession has been outlined, and a fair but very crude knowledge of the earth's history reached. So far as palæontology and stratigraphy can speak, they tell us a good deal, but we cannot realize the meaning of it all without the aid of correct physical conceptions to reveal the processes of the wonderful earth-history which lies buried under our feet.

It is with this object that I ask your indulgence this evening in mentally travelling with me over the British Isles to see what help we can get from known British geology.

¹ In the discussion on this paper it was stated that the Dora Baltea, though thick with glacier mud, contains excellent fish.

² Presidential Address to the Liverpool Geological Society, 1895.