pieces of flint irregularly chipped at the edges, but not apparently 'formed' in any definite way.

In chalk wash-mills, as in the examples mentioned, much must depend on the proportion of the flints to the mass of the chalk and on their size, as the more numerous and the larger the flints, the more will they be affected, and *vice versâ*. Thus the power of the mill, as able to shape Eolithic flints, must, in the cases observed by me, be considered as non-proven.

The difficulty of the whole question consists in this, that we are trying to decide where no final decision seems possible. For those who hold that certain flints are due to natural causes have never seen, or can see, Nature doing what they would refer to Nature, and those who uphold the human origin of the flints could never, of course, have seen them actually made by man. But we have actual proof that man has and does fashion certain stone tools, and therefore have good reason for asserting that man did make some of these early tools, and we also know that man improves on his early work, so that the best forms of these cannot be man's earliest efforts. The difficulty always will lie in fixing the starting-point of his 'prentice hand.

The stages in the progression from the ruder to the more perfect forms were probably these. As soon as man found that some adjunct to the hand was needed in his conflict with Nature and the beasts, sticks, bones, shells, and stones were used. Of these, only stones, for the most part, have remained.

The stones, in the first instance, would be those best adapted to his needs, and were so selected. Next it might occur to him that he might imitate those *natural* forms: hence the difficulty to distinguish between the apparently natural forms and the possible artificial ones, both having only one sharp or sharpened edge. Then he would gradually learn so to adjust the angle of incidence as to extend the chipping all over the flint, and at last to select the kind of flint that gave the best results. The process must have been a gradual one, with intermediate stages, with reversions perhaps to older and ruder forms, and the difficulty will always lie in fixing the starting-point of the undoubted artificial stage, and I do not think that the wash-mill evidence will help to do this. But it may cause those who have been too ready to accept worked flints to be more careful in the future.

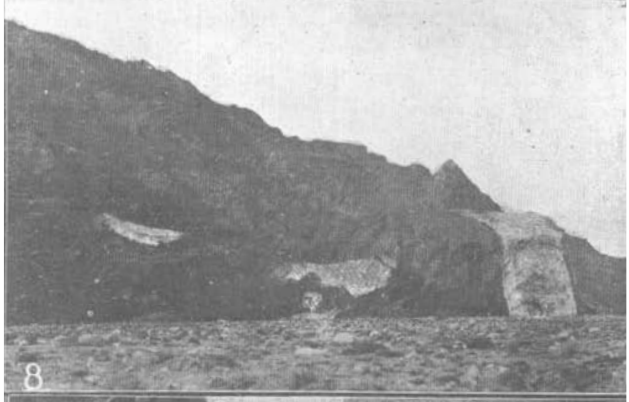
VI.—Further Notes on the Stratigraphy and Fauna of the Trimmingham Chalk.

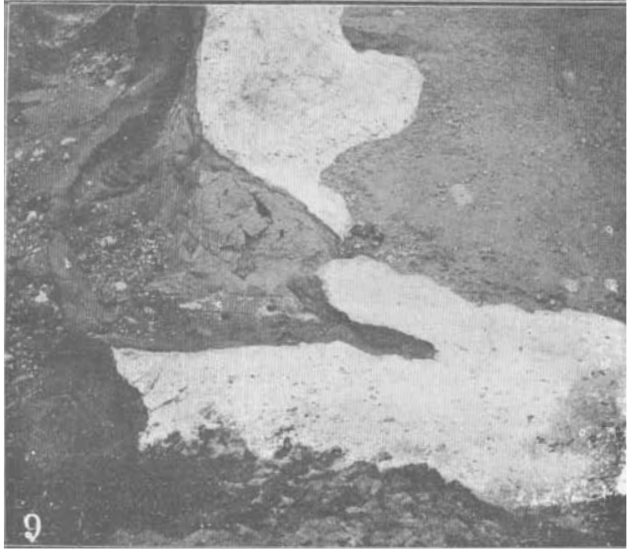
By R. M. Brydone, F.G.S.

(PLATES IV AND V.)

(*Continued from the January Number, p.* 22.)

DOWNWASHED sand and mud much obscured the section, but the clay appeared to be definitely continuous, while the chalk might be continuous under the mask of mud, but did not seem likely to be so. The section suggested very strongly a flat sheet of clay





pushed at a level some way below the beach against a backward sloping and then overarching surface (e.g. the side of a cave), which it had followed until doubled back upon itself.

The masses of chalk in the bay, where accessible, all showed *Ostrea lunata* chalk, except the stringer from the bluff. This was accessible from above, and was then composed solely of the grey chalk.

It was quite clear that the landward face of the bluff was not parallel to the coastline, but ran about east and west, the bluff being therefore a rude triangle with its apex towards the north. The landward face was covered by what appeared to be crushed blisters of finely laminated clay apparently formed round projections in the surface of the chalk.

In the Autumn of 1904 I got desperate at my inability to satisfactorily sketch the constant changes which were taking place, and borrowed a camera, and since that time I have a fairly continuous series of photographs, some of which are reproduced as Figs. 6 to 18 in the plates illustrating this article. Unfortunately I had had no previous experience of photography, and I have always chanced upon dull and cloudy weather, so that I may be forgiven for the imperfection of the photographs. As it is, they show far more than I ever dared to hope for. They are all, I think, self-explanatory except Fig. 9, which was taken from the summit of the bluff, and in which the boundaries between the grey chalk above and below and the *O. lunata* chalk between is traceable in the 'slope' (the nearer piece of chalk) by a slight variation in shade.

During the period covered by these photographs erosion has been very rapid at this point (the clay seen on the left hand of the bluff in Fig. 13 was faced with chalk of fair thickness six months previously) (Fig. 8), and several further points of interest have been disclosed. The most important is perhaps that shown in Figs. 10, 11, and 15. The cutting back of the main cliff has provided a section across what appears to be an erratic mass of rudely stratified flint shingle, varying from very coarse to fairly fine, with a bed of sand in the middle and a long thin slice of chalk at its left hand, the stratification being vertical. The slice of chalk, though nowhere more than two feet thick, contains both *O. lunata* chalk and grey chalk with an occasional grit seam at the base throughout the whole length I have been able to examine, the *O. lunata* chalk being next the clay which forms as it were the backing of the mass. The lower end of the chalk slice was recently exposed, and the clay was seen to run down beside it and then turn at right angles in under it (Fig. 15), with the banding parallel to the surface of the chalk, which seems inseparable from the junction of clay and chalk here. The whole thing very strongly suggests a piece of shingly beach set on end, the chalk representing the basement bed on which the shingle was heaped up. The rude stratification of the shingle is what might be expected from the sifting together of the pebbles of similar size which takes place in every beach, the coarsest part being that next the chalk. This huge mass of shingle, which can hardly

have been transported from any distance, as it would not have held together, forms an interesting parallel to the masses of coarse shingle which lie on the top of the northern part of the south bluff as recorded in my previous pamphlet (see also Fig. 1 hereto).

Another point of interest is the behaviour of the grey bed in the seaward face of the bluff. As this was cut back the grey bed developed a deep pocket, shown just beginning in Fig. 7 and complete in Figs. 13 and 17, at the bottom of which the gritty basal seam thickened considerably and became exceptionally coarse. (It will be noticed in these figures that the two upper flint beds shown in fig. 1 of my previous pamphlet have become comparatively indistinct, while the third has become very marked. At the moment of writing the second is regaining its importance.) On the left-hand side of this pocket the base of the grey chalk rises very sharply, so that the chalk which strings out into the clay, thin as it is, becomes, as on the other side of the bluff, composed of a layer of *O. lunata* chalk below and a layer of grey chalk above. There is clearly at this point a very strongly marked unconformity between the two beds of chalk.

Another point is that *O. lunata* chalk has come in between the grey chalk and the clay in the cross section at the end of the north side of the grey chalk bay and at several other points in this mass where the grey chalk and clay were previously in contact, so that it seems fair to assume that the distance by which the grey chalk overlaps the *O. lunata* chalk is slight everywhere. Whenever the grey chalk has been removed from off the *O. lunata* chalk beneath it the latter has always presented a decidedly wave-worn and smoothed appearance.

This grey chalk, as before stated, presents some remarkable peculiarities besides its basement bed of grit with flint and chalk pebbles. It is very soft, but contains a great abundance of hardish lumps of varying shades of grey which are not clearly rolled, but have very smooth and suspicious outlines. These lumps are very similar in texture, and, so far as I know, identical in fossil contents with their grey matrix. The flints present two facies. One, which is generally small, is dark grey throughout and very soft, being often little more than a central mass of spongy texture, but no definite shape, surrounded by a very thin skin, very imperfectly silicified and easily cut with a knife on slight pressure. The other type appears to be confined to the base of this chalk, and includes nearly all the large flints. It is very thoroughly silicified and black inside with little or no cortex, and light bluish grey outside. These, like the included lumps, suggest gentle rolling, but contain only the same fossils as those of the grey matrix, including the peculiarly characteristic ones, and certainly no specimen of *O. lunata*, which occurs in profusion in the flints of its own horizons. The bed as a whole is certainly not reconstructed, for the grey matrix abounds in fragile fossils in absolute perfection, the most striking being *Ostrea inæquicostata*, bivalved *Ostrea ungulata*, and numerous branches of *Vincularia* and other Polyzoa. The fossils show the

unconformity between the grey chalk and *O. lunata* chalk as clearly as the stratigraphy. *Ostrea lunata* and the bun-shaped *Echinoconus* are unknown in the grey chalk, which is full of *Ostrea inæquicostata*, *O. canaliculata*, and *Terebratula obesa*, none of which have ever yet been found in the *O. lunata* chalk. There are very similar grey beds on the foreshore underlying white chalk without *O. lunata*, which passes up into *O. lunata* chalk, but below they are cut off by a fault, and until we know either what overlies the grey chalk of the bluff or underlies the grey chalk of the foreshore it is not safe to identify the two sets of grey beds, though it is very tempting, the similarity being very striking, especially in the fossils.

At the beginning of October, 1905, the clay behind the bluff was broken through by the waves, and by the middle of the month the bluff had been completely isolated and a secondary bluff formed behind it out of the seaward face of the *O. lunata* chalk underlying the 'slope' of grey chalk, which had by this time become mainly a slope of *O. lunata* chalk showing several lines of flint dipping gently seaward. The cross section of this secondary bluff showed gently arched lines of flint, from which it was clear that this secondary bluff was the top of a gentle anticlinal fold rising towards the land, exactly like the ridge forming the southern part of the south bluff. It was, however, underlain where its base was clear of sand by clay visibly continuous in the south bay with the clay underlying the chalk masses. The same waves that had breached the clay pinnacle had also cleaned the section in the south bay, which is recorded by Fig. 17. The clay appeared to have pressed upwards from under the mass of chalk nearer the bluff and carried up with it on its surface the mass high up in the cliff, for the two were connected by a very thin but unbroken line of chalk which kept the clay above the masses of chalk from quite touching the clay which emerged from beneath them. A similar but more partial appearance was presented in the north bay by the clay which emerged from under the 'slope' and passed up into the cliff, only to arch over and, as before stated, pass down beside and in under the erratic slice of chalk. Both the masses in the south bay, i.e. the lateral section of the 'secondary bluff' and the mass seen high up in the cliff, were composed of *O. lunata* chalk with about a foot of grey chalk above separated by the regulation grit seam with pebbles, and above the grey chalk came about six inches of very regularly bedded sharp grey sand with one interlaminated seam of black clay, and above the sand about 2 feet of dark bluish grey clay. Between the two masses of chalk the sand was cut out by the clay above it, but over the masses themselves it was very regular. Above the bluff it passes into a coarse gravel.

The most recent exposures of the north side of the bluff itself appear to show an actual inversion of all the chalk below the thick flint. These flint lines are not clearly marked on this side, but their appearance is quite consistent with and indeed suggestive of their being actually inverted, and the hypothesis that they are actually

inverted is made very probable by the fact that the seams of *O. lunata* up to and including that immediately below the thick flint follow the same inverted course, a fact pointed out to me by Mr. Bidder. Now it will be remembered that the *O. lunata* chalk was continuous across the gap, and that the gap was quite recently fairly narrow, and though no bed of flint happened to occur in the arch of *O. lunata* chalk crossing the gap, I am convinced (and Mr. Bidder is equally positive) that the thick flint in the bluff was identical with the flint line at a corresponding height in the 'secondary bluff' (Fig. 14). If we are right, then the thick flint was not involved in the inversion. That being so, we should expect to find filling the gap which would otherwise be left between the thick flint which continues more or less horizontal, and the beds below which break away from it, an area of reconstructed chalk, and this is exactly what does occur there. The sketch below will show what is meant:—

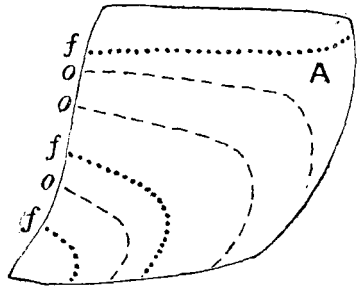


Diagram-sketch of the north-west face of bluff.

f, f, f, flint bands; *o, o, o,* seams of perfect *O. lunata* in section.
A, area composed of chalk crowded with comminuted *O. lunata* and no other fossils.

Now I think we are entitled to assume (until the contrary is shown) that the inversion is a result of the same, or practically the same, force which has so greatly tilted the beds which are not actually involved in the inversion, for both the tilting and the inversion must have been produced before the deposition of the grey chalk on the upturned ends of the tilted strata, since neither the tilting nor the inversion has affected the grey chalk, and that fixes the tilting and the inversion as of late Cretaceous age. Evidently all the beds now appearing in the bluff were tilted together, but by the time the angle had been reached at which the uninverted beds now stand, these beds must have been raised above the plane at which the thrust was operating, and the lower beds, being still in that plane, must have been forced to part company with the uninverted beds, no great matter, as the whole could by that time have only been lightly consolidated, and turn under themselves. This view conforms very well with Lyell's figure of the bluff when it was about twenty times its present length. This figure shows at the north corner a small area of chalk with a steep dip which

flattens out southward to quite a gentle dip over a comparatively very extensive area, showing the steep dip to be very local. Probably we have in the bluff of to-day a remnant of the steeply dipping area only of Lyell's bluff, but whether that is so or not Lyell's figure is a very strong argument against assuming the general prevalence of a steep dip at this point.

The only possible explanation of these local phenomena seems to be one on the lines of the original and ingenious theory of Mr. Clement Reid, varied by postulating the lateral thrust as of Cretaceous age, directed almost due south and very local, and leaving the thrusting agent altogether indefinite. Except at this very point the thrusting force only created a gentle anticline. This anticline of greatly varying sharpness must have been exposed to denudation, which planed off the upper part and more or less flattened the sides, and the surface so formed was then resubmerged and the grey chalk deposited on it to a minimum thickness of three feet. At some date shortly before the formation of the glacial beds, the chalk must have been again raised and exposed to a south-westerly sea, which formed caves in it which were filled by the first inflow of boulder-clay. The bottoms of these caves are probably well below the present beach level, and we only see horizontal sections through the roofs and the upper surface of the infilling clay, which of course then appears to be underlying the thin edge of the broken-through roof by natural deposition. The detached masses of chalk seen in the cliff behind the bluff have clearly been carried up by a mass of clay from below, and represent parts of the roofs of these caves, which were too weak to resist the upward pressure of the clay. Possibly this upward pressure was applied at a much later date than the infilling of the caves, for the thin line of chalk recorded as connecting two masses of chalk is strongly suggestive of chalk, so to speak, rolled out between the upper and lower clay, and this could only take place by a fresh movement of the lower clay after the upper clay had taken up its present position. It is also suggested by the regular blending of the deposits immediately overlying the chalk just at this point that after the first influx of clay had filled up the sea bed to the level of about the top of the chalk there was an interval, during which the above-mentioned regular deposits were formed on the new sea floor so created, before this sea floor was covered by the upper clay, and then broken up by renewed motion in the lower clay.

5. *Other Exposures.*

A new feature of interest is the exposure for a short time of a patch of *O. lunata* chalk, about 30 yards by 12, some 340 yards to the south of the south bluff, i.e. roughly, intermediate between it and the short ridge exposed some years ago at the foot of the cliff under the brickfield (which latter I will call for convenience the brickfield chalk). This new patch of chalk was practically touching the base of a great mass of firm clay which forms at present the first headland to the south of the south bluff, and appeared to pass

under this clay in the cliff and also under clay to the northward, its other boundaries being formed by sand. It appeared to represent the top (or rather a section across the upper part) of a flat ridge running and sinking in the usual direction about 30° south of east. Its southern and eastern ends were capped by a practically continuous sheet of flint, identical in appearance with a sheet of flint which I had previously observed on the foreshore close by coating one side of a ridge of *O. lunata* chalk heading in this very direction. The brickfield chalk recorded in my previous pamphlet I have never seen again, but once or twice in 1900–1904 there just showed through the sand some way further down the beach a narrow ridge of *O. lunata* chalk once visible for as much as 30 yards, and apparently running out to sea in much the usual direction, and in a line with the first recorded brickfield chalk. This ridge has been frequently just visible during 1905, and in October, 1905, it was gradually exposed to a length of over 66 yards. It was nowhere more than 4 feet and rarely more than 2 feet thick, and dipped very steeply to the north. It seemed very remarkable that such a long thin ridge should have been preserved on a foreshore, though there were strong indications that it increased greatly in width at a very short distance deeper down. But a still more remarkable thing was revealed on close examination, i.e. that throughout practically its whole length it was composed of a layer of *O. lunata* below and a layer of grey to white chalk above, separated by a grit bed full of rolled flints and chalk, and agreeing most exactly, except for its greater thickness (maximum at least 6 inches) and the greater size of the flint pebbles, with the grit bed at the base of the grey chalk in the north bluff over a mile away. I have little hesitation in identifying the two grit beds, for though the brickfield chalk above the grit bed was not uniformly grey, it contained many hardened and apparently rolled lumps of chalk. I could not find there any of the characteristic grey chalk fossils, but the total amount of chalk exposed was very small, and the physical identity is very pronounced.

EXPLANATION OF PLATES.

Views of Trimmingham Chalk Bluffs, Norfolk Coast.
Various views of the North Bluff and the exposures in the bays on either side of it.

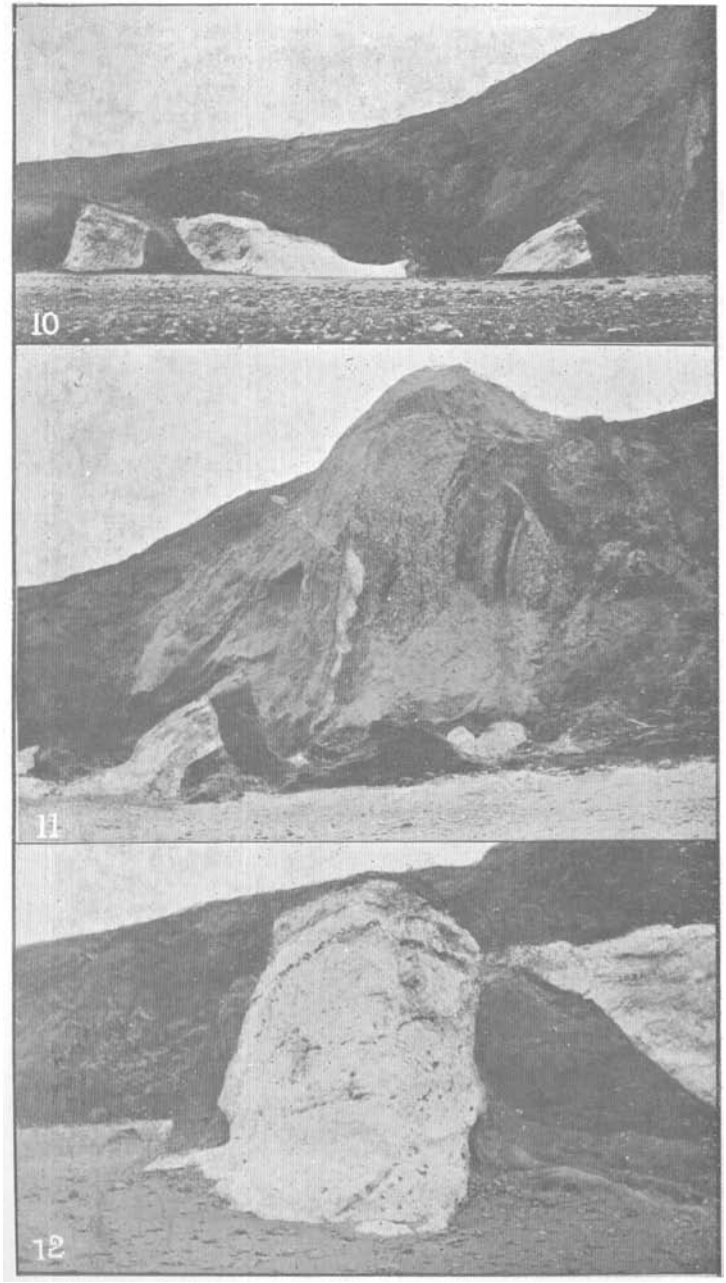
Plate IV.

Fig. 7.—Photograph taken November, 1904.
,, 8.—South bay; November, 1904.
,, 9.—Head of north bay from top of bluff; May, 1905.

Plate V.

Fig. 10.—North bay, showing slab of chalk on end in cliff; April, 1905.
,, 11.—Showing slab of chalk and mass of stratified shingle on end; May, 1905.
,, 12.—North Bluff, seaward aspect; May, 1905.

(*To be concluded in our next number.*)



Views of the Trimmingham Chalk Bluffs, Norfolk Coast.

(To illustrate Mr. R. M. Brydone's paper.)