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XV. *Remarks on the Position of the Upper Marine Formation exhibited in the Cliffs on the North-east Coast of Norfolk.*
By Mr. RICHARD TAYLOR of Norwich.

To the Editors of the Philosophical Magazine and Journal.

THE accompanying sketch (Plate I.) represents the section of about a quarter of a mile of the cliff immediately to the west of Cromer Jetty, at a point which attracts the notice of the geological observer to the singular contortions of the diluvial beds; and is further remarkable by the singular position and expansion of the crag strata.

In pursuing the line of cliffs from their commencement at Weyburn Hope, a thin bed of ferruginous gravel and clay may be traced, almost uninterruptedly, along the coast, for about seven miles, to this spot. This bed seldom exceeds two feet in thickness, and for the most part is visible immediately overlying the upper chalk series, which rises to the surface about three miles west of Cromer. An apparent continuation of the same bed may be traced from hence southward, about fifteen miles; appearing in general, just above the high-water mark, sometimes laminated and often contorted or waving, and varying at every hundred yards its component qualities, through every modification and combination of ferruginous and ochreous sand, gravel, clay, peat* and loam, with more or less of compressed wood; stumps of trees rooted into the stratum; ochreous nodules and nuclei; shelly and bony fragments; teeth, tusks and horns of elephants and deer; in all which properties it preserves a certain general and remarkable character by which it can be identified throughout an extensive line of the eastern coast, occupying the position usually assigned to the crag or upper marine formation, and which I have previously noticed in the article in volume lx., August 1822.

* In one of these peat beds I observed a numerous colony of recent and living *pholades*.

The opinion there entertained that this osseous stratum is an extension of the Harwich bed, containing similar remains, has been very recently confirmed by the knowledge that large bones have been collected at Ormesby in Norfolk, and Corton in Suffolk; elephants' teeth near Southwold; and recently elephants' teeth are stated to have been raised by the fishermen in their nets off Yarmouth. It was to be expected in the low ground, between Caister and Gorleston, originally covered by the sea, that this stratum, although continuous, was situated considerably below the low-water mark. The same observation applies in passing Winterton, northward, towards Happisburgh; along which line this stratum is in general only to be traced by its *debris* thrown upon the beach.

Besides the bones which are above noticed and those formerly mentioned in Phil. Mag. vol. lx. p. 82, a small tusk has been recently taken out of the ferruginous stratum near Happisburgh. I have also in my possession many mineralized bones, which at different times have been entangled in the nets of the fishermen, at a considerable distance at sea, opposite the Norfolk cliffs, towards Happisburgh; affording an additional proof of the great space over which this osseous deposit has extended. Of these animal remains no arrangement or scientific examination has at present been attempted; nor can I here venture to describe them but in general terms. They appear to be referable, chiefly, to species of the elephant, the ox, and the elk; consisting of

Two vertebræ, about six inches in diameter.

Fragment of a tusk which, if entire, would have measured six inches diameter.

Twelve teeth, or fragments of teeth, of elephants.

One fragment—probably the superior part of the femur of the elephant, the greatest width being eight inches.

Several portions of bone, detached fragments of the larger bones, perhaps, of elephants.

One horn, eleven or twelve inches long, and about ten inches in its greatest circumference; probably of an animal of the ox kind,—but I am not able to determine.

The upper portion of the skull apparently of the large fossil elk, the "*cerf à bois gigantesque*" of M. Cuvier; width of the front six inches; circumference of the beam of the horn about nine inches.

A part of the horn of a similar animal, the brow-antler broken off; measures eight inches and a half.

Part of the forehead and commencement of the horns of a smaller species of elk.—In four specimens of this portion
of

of the skull of the stag or elk, a material difference in their size and proportions is observable.

One or two small portions of the leg-bones of the elk or stag.

To return to the more immediate subject of this communication. Near the base of the cliff, represented in the Plate, indurated beds of crag sand, with abundance of its peculiar fossil shells, here consisting chiefly of small *Mastra arcuata*, *Cardia*, *Mya lata*, *Turbo littoreus*, and fragments of *Balani*, are exposed at low water upon the beach.

It is remarkable that at this spot the crag suddenly enlarges, from a small bed a foot and half in thickness, to a series of beds occupying almost the entire cliff more than a hundred and twenty feet high, and about two hundred yards wide; filling up a sort of gap in the accumulated deposits of the diluvial clay formation.

There is a further peculiarity: whilst the thin stratified crag, which appears at low water at the base of the cliff, contains chiefly perfect or unbroken shells, the whole of these extended superior beds contain comminuted fragments only; a fact which, in conjunction with other circumstances, leads at once to the conclusion that a great disruption of the regular strata, through the powerful agency of currents of water, has taken place since the deposition and consolidation of the chalk. Numerous instances corroborative of such an opinion may be observed within the space of a few miles; some of these may perhaps be particularized in a future article.

The crag shells are here dispersed, in fragments, throughout a series of horizontal beds, alternating with gravel and whitish sand, and occasionally with thin seams of loose peat.

The dry and loose nature of these, like all the other crag sands wherever noticed, subjects them to the continual operation of slipping down the cliff and forming heaps at its base.

The position of the formations bounding this unusual accumulation of crag, is best understood by a reference to the plate.

Here some singular curvatures, inversions and contortions of the strata present themselves; but are with difficulty represented on a scale so limited. Detached masses, lumps and veins of chalk; contortions and tortuous veins of blue clay, gravel and sand, arrange themselves in a variety of forms; passing through the thick formations of consolidated mud of which the cliffs are chiefly composed along nearly 25 miles of the Norfolk coast. This mud is divided into two beds, chiefly distinguished by the difference in their colour and density.

At the base lies the bed of ferruginous, peaty and laminated clay, before adverted to; here, as in frequent instances, disposed in an irregularly waving or serrated line. Above this is heaped a mass of dark blue mud or clay varying from ten to near a hundred feet thick; frequently containing small chalky concretions, and sometimes pyrites and rounded fragments of the older rocks, but possessing no peculiar organic remains; none, indeed, save a few solitary pieces of belemnites or gryphea, and the shells contained within the bouldered fragments of indurated clay. Over the blue clay is the brown mud or clay, less compact than the former, full of springs, and remarkable throughout its course for the contortions which it exhibits. This also, for the most part, is barren of organic deposits, except a few diluvial waterworn fragments: at the spot we are describing, we have to notice a remarkable departure from this character. A large portion of the brown mud, occupying the space between the great contortion at A and the crag sand at B, contains comminuted crag shells dispersed through the mass. These, and the detached masses of chalk in the position shown in the sketch, afford further proofs of the local disruption and partial dispersion of portions of the preceding older deposits.

I am acquainted with no corresponding instance of the dispersion of crag shells through the adjoining clay beds in the progress of this stratum through the interior of the county of Norfolk.

Since the sketch was placed in the engraver's hands, a more attentive examination has convinced me that broken portions of crag shells are abundantly interspersed through the mass of the clay formation, particularly of the upper beds, for a mile or two of the cliffs on each side of Cromer. These fragments are so small, although abundant, that it is not surprising that they were so often overlooked before.

Traces of the crag formation are plentifully exhibited, at that part of the cliffs upon which Foulness light-house is situated. Here the diluvial clay or mud formation attains its greatest elevation during the whole of its course along this coast. The section of the exposed clay beds was measured by the writer, and found to be 270 feet of perpendicular height; above which are horizontal deposits of gravel and sand, 40 to 50 feet more. The whole of this accumulation of 270 feet contains comminuted crag shells intermixed with small chalky fragments*.

The sand beds at Foulness light-house are probably 150

* Messrs. Conybeare and Phillips consider 30 feet as the thickness of this stratum at Harwich and Walton Naze; and this, perhaps, is more than an average thickness.

feet thick ; but I have not detected therein any traces of crag fossils, although they abound in the clay, in an extensive gap of which these horizontal beds are deposited.

At A commences the most extensive contortion hitherto displayed in the diluvial formations of this district. It consists of concentric bands of gravel, sand, and brown mud ; the external mud vein contains minute fragments of crag shells. There are few visitors to Cromer, probably, but are struck with this singular feature in its cliffs. The foot of this contortion rests upon a bed, 15 feet thick, of yellow sand without shells, overlying the waving laminated and peaty clay bed before described ; and the entire section exposed was found on admeasurement to be 90 feet.

The general composition of the cliffs, for many miles to the west and south of the portion here represented, is chiefly an accumulation of the consolidated diluvial mud ; varying in thickness from 20 to 250 feet ; occasionally divided by vertical gaps, which have been subsequently filled with chalk, marle, or sand, but chiefly the latter. Some instances occur, where the beds of mud and other diluvial deposits assume a vertical position. These, and the gaps alluded to, often cut through the mud cliffs from the summit to the base, at the particular part where the accumulation is the greatest and the elevation is the loftiest. The most remarkable examples of this occur at Paston Hill, at Beck Hythe, at Cromer, Runton, Beeston, and Sherringham.

Extensive slips of enormous masses of the diluvial clay are constantly occurring ; and avalanches of mud are continually in operation, particularly between Cromer and Mundesley. They are occasioned rather by the numerous land springs and by interruptions to the natural drainage, than by the undermining action of the waves ; and the accumulating mass forms an inaccessible and impassable border of soft boggy mud, often several hundred yards in width, and 100 or 150 feet in thickness, destitute of vegetation, and presenting a gloomy and desolate aspect for some miles.

The annexed drawing is chiefly copied from a section constructed on a large scale, by the writer of this article, of the entire line of cliffs on the Norfolk coast ; from the point where the diluvial beds rise from beneath the Marum sand hills, north of Winterton, to where the high land recedes from the shore near Cley at Weyburn Hope.

Yours &c.

RICHARD TAYLOR.

Norwich, Dec. 15, 1823.