

NOTICES OF MEMOIRS.

ABSTRACT OF A PAPER ON "THE GLACIAL AND POST-GLACIAL STRUCTURE OF NORFOLK AND SUFFOLK." By MESSRS. SEARLES V. WOOD, JUNR., and F. W. HARMER.¹

(Read before the British Association at Norwich, August 20, 1868.)

THIS paper was a summary of the results arrived at by the authors, from a survey and mapping of the Crag and Glacial beds of Norfolk and Suffolk, upon the Ordnance (one inch to the mile) map, which they have been carrying on during the last four years. The paper was illustrated with a large map, constructed from their survey map, and copious detailed sections, traversing the counties in various directions, without which the paper itself is difficult to be understood. The principal results at which the authors have arrived at are as follows:—

That the Fluvio-marine Crag of Thorpe, and Bramerton, and of Wangford, Bulchamp, and Thorpe, near Aldboro', is coeval with the newer part of the Red Crag.

That the Crag of Burgh, Horstead, and Coltishall, in the Bure Valley, is a fluvio-marine development of the Chillesford shell bed, or Crag of Easton and Aldeby, which, divided from the Red and Fluvio-marine Crag by an interval of sand of varying thickness, overlies the Red Crag at Chillesford, and the Fluvio-marine Crag (or old Norwich Crag) at Thorpe and Bramerton.

That the so-called Crag of Belaugh, in the Bure Valley, and the so-called Crag of the Weybourne and Cromer coast, are newer than the Chillesford beds (which, unless the pebble beds next mentioned be a still higher part of the Crag series, form the uppermost of the true Crag series), being characterised by the presence in profusion of a shell unknown to any bed of the true Crag series from the Chillesford clay downwards—viz., the *Tellina solidula*; and were introduced after an elevation of the Crag area had converted the southern portion of it into land, and given rise over the northern portion to extensive sands with pebble beds, which rest on and indent the Chillesford clay in that northern portion. These sands with pebbles occupy in the south of Norfolk, and north of Suffolk, the same place relatively to the contorted Drift as is occupied on the Cromer coast by the Weybourne sand (or so-called "Crag" of the Cromer coast), the Cromer Till, and the indenting sand (or bed C after-mentioned). These pebble beds may thus represent in time either the whole or any one of the formations A, B, and C (described further on); or they may form merely the closing bed of the true Crag series,² in which case the Weybourne sand, the Cromer Till, and bed C are entirely unrepresented in the south of Norfolk and north of Suffolk.

That the forest beds of the coast extending from Eccles to

¹ The abstract has been most obligingly prepared and furnished by the authors expressly for publication in the GEOLOGICAL MAGAZINE.—EDIT.

² The authors are inclined to think that the second of these alternatives is the true one; and they hope to clear up the point by means of a fossiliferous pebble-bed near Bungay.

Weybourne, with their associated sandy clays of freshwater origin, (being the oldest beds exposed along that coast, and having been partially destroyed by the denudation of the sea depositing the so-called Crag containing *Tellina solidula*), represent a land surface of some period anterior to this so-called Crag. That as this period extends from the close of the true Crag series downwards, such land surface may be either contemporaneous with the true Crag series (which has no place on the northern coast of Norfolk), or may be of a period intervening between the close of that series and the actual submergence of northern Norfolk, which was accompanied by the introduction of *Tellina solidula*, and the accumulation of the Weybourne sand, or so-called "Crag" of the Cromer coast.¹

That the Mammalian teeth and jaw fragments of *terrestrial* Mammalia (generally more or less rolled), obtained as yet from the Fluvio-marine Crag and Chillesford beds, do not represent the Mammalian fauna of the deposit in which they occur, but are derivative from some older bed.

That, contrary to the views of the Rev. John Gunn and others, who discover an Upper and Lower Boulder-clay in the cliffs between Weybourne and Eccles, and identify the former with the great Boulder-clay formation of the East of England, the authors regard everything in those cliffs as inferior, not only to the great Boulder-clay, but also to the extensive sands and gravels termed by them Middle Glacial; these sands and gravels (which underlie a large part of the great Boulder-clay in the counties of Norfolk, Suffolk, Essex, Hertford, Buckingham, and Leicester,) only capping with their base the cliffs in places, but in greater mass forming the sand hills, which immediately inland occupy higher ground than the top of the cliffs, and are spread extensively over northern Norfolk.

That all the beds of the cliff-section between Eccles and Weybourne (except the patches of the base of the Middle Glacial sands, which in places cap it,) form a series of themselves which they term the Lower Glacial, and are throughout characterised by the presence of *Tellina solidula*. These are divisible into the following, which are given in the *ascending* order.

A.—The Weybourne Sand, the base of which, when resting on the Chalk, is often occupied by an accumulation of shell-patches known to collectors as "The Norwich Crag" of the coast. This sand becomes, east of Cromer, charged with lignite, and often laminated with bands of lignitiferous clay, in which condition it constitutes the "laminated series" of the Rev. John Gunn. In that condition it is unfossiliferous, the lignite intermixture apparently rendering it unsuited for molluscan life, of which the remains are usually

¹ The authors would observe that the position of the bed yielding wood and Mammalian remains beneath the Middle Glacial sands at Kessingland Cliff in Suffolk, seems, from its position relatively to the Chillesford Clay, two miles distant, to be clearly subsequent to the close of the Crag series; but whether this bed be synchronous with the whole of the Forest and freshwater deposits of the Cromer coast, or whether the latter may not represent a much longer duration of land surface—a duration embracing the period of the Kessingland bed, but reaching back into the Crag period—must be determined by the paleontological evidence only.

present when in its pure condition. This sand passes up by interbedding into :—

b.—The Cromer Till, or “Lower Boulder-clay” of Mr. Gunn, a sandy clay with numerous small stones, and with occasionally a boulder of larger dimensions.

c.—Sands which, where the cliff is uncontorted, are seen to be indented into a deeply eroded surface of the Till, and to have themselves been also denuded, so as to form an even floor for the ensuing formation, viz.,

d.—The Contorted Drift. This bed is the widest spread of the Lower Glacial series. It begins in the north of Suffolk as a reddish brown brick-earth, a few feet thick, resting on the sands with pebbles, before described, but sometimes the pebbly sands have been removed. It comes up at the base of Pakefield and Corton cliffs (where, as well as in the sections at Bishops Bridge, Norwich, it is called by Mr. Gunn and others “Lower Boulder-clay,”) and thickening rapidly as it extends northwards, comes out at the eastern termination of the Cromer coast section at Eccles, as the well-known Contorted Drift of that coast, from whence it extends continuously, and as the uppermost bed of the cliff (except the sand cappings) to Weybourne. The authors state that they have traced it from its attenuated commencement in the north-east of Suffolk and south-east of Norfolk in every direction northwards, and found it at Cargate Green, near Acle (ten miles only south of the Cromer coast), overlaid by the great Boulder-clay (or Upper Glacial), and at West Somerton (seven miles south-east of the Eccles termination of the coast section) overlaid by Middle Glacial sand, and that again by the great Boulder-clay in direct superposition. In its brick-earth condition it is sometimes full of small stones, occasionally also of minute chalk fragments, and often contains large sand-galls. In the direction of Weybourne this deposit becomes more marly by the intermixture of fine chalk sediment; and west of Mundesley, at which place it begins to be contorted, great masses of pure white marl or reconstructed Chalk (which have been described as chalk-masses by observers,) occur in it, which, by the weight of the bergs carrying them, have sunk in some cases into the subjacent Till, and even into the Weybourne sand. These marl masses the authors describe as being detached fragments from the more inland portion of the Contorted Drift itself; which, inland from the coast, both southwards towards Reepham and Holt, and westwards towards Wells, becomes formed exclusively of this marl. They attribute the formation of this marly portion of the Contorted Drift to a discharge of ground-up Chalk from the *debouchure* of a Glacier that occupied the Chalk country of Cambridgeshire and West Suffolk; the brick-earth which forms the easterly development of the Contorted Drift, being due to a river discharge in that part; the two sediments intermingling in the intermediate area, and producing the alternations of marl and brick-earth there presented by this formation. The detached masses of the marl were, they consider, introduced into the brick-earth portion of the deposit by the agency of bergs, which,

breaking from the Glacier and grounding, picked up masses of the marl forming over the sea-bottom in that part of the area. These masses the bergs carried out into the area where the brick-earth was accumulating, and grounding again, imbedded them in the brick-earth, and even in the subjacent Till and Weybourne Sand, contorting the beds in the process. From detached portions of this marl, which they have found as far south as Claydon, near Ipswich, and Stanstead, near Lavenham, in Suffolk, they infer that this deposit covered the west of Suffolk and Norfolk, but underwent great denudation in the former part by the waters of the Middle Glacial sea, the sands of that sea, west and south of Diss, lying up to bosses of it in some parts, and overlying it in others.

That the fauna of the lower Glacial beds is marked by the disappearance of all except the boreal and arctic mollusca of the Crag, rather than by the introduction of a new fauna, the principal introduction being the *Tellina solidula*. A list of 28 species of mollusca was given by the authors from these lower Glacial beds.

That the sands and gravels, attaining frequently a thickness of fifty or sixty feet, which underlie much of the great Boulder-clay in the six counties before-mentioned, and which, termed by the authors the Middle Glacial, pass over the Lower Glacial series, A, B, C, and D, just described, contain a molluscan fauna of which they enumerate 23 species. The interest attaching to this fauna consists in the fact that *Pectunculus glycymeris*, which dies out in the newer part of the Red Crag, and is excessively rare in the Fluvio-marine or true Norwich Crag, returned during this formation in abundance, as well as *Ostrea edulis*, a shell which similarly disappears in the newer beds of the Crag, and it is not known now within the Arctic circle. Although a bed, a few feet thick, of Boulder-clay identical in composition with the great Boulder-clay, but of very limited extent, occurs at the base of this formation at two places in north-east Suffolk and at one place in Hertfordshire, its features and fauna both appear to indicate that some considerable amelioration of the very severe climate to which the marl of the Contorted Drift that preceded it was due, occurred in the interval occupied by this formation.

That the true wide-spread Boulder-clay of the east of England, termed by the authors, the Upper Glacial, ceases from denudation in northern Norfolk, along a line drawn from Winterton on the north-east coast to Norwich, and thence passing near Aylsham through Cawston, Guestwick, and Barney, to a point a little north of Fakenham. On the east of the county, that is to say, to the south-east of a line joining Norwich and Happisburgh, the Middle Glacial sand and the underlying contorted Drift crop out from beneath the true Boulder-clay, in regular sequence; but over the centre of Norfolk the authors describe a very anomalous structure, which is that the true Boulder-clay (or Upper Glacial) has been deposited in a great trough more than twenty miles wide, which has been excavated through the Middle Glacial sands and subjacent Lower Glacial beds down to the Chalk. The effect of this has been to bring the true Boulder-clay (or Upper Glacial), resting on the Chalk, down to a level on the west and south-west of Norwich, which in

some parts is below that of the Crag, and nearly 100 feet below the position which it occupies when resting on the older Glacial beds in undisturbed sequence of deposit, the Chalk upon which the Upper Glacial thus rests direct, being generally in a glaciated or disturbed condition.

That over the central part of Norfolk, where the Upper Glacial thus goes down in solid mass to the Chalk, it is overspread by extensive beds of Post-glacial gravel,¹ which not only cap the plateaux, but spread over the sides of the valleys, sometimes forming a continuous wrapping sheet down to their bottoms, and presenting a general absence of terrace structure. These features the authors consider as repugnant to any theory accounting for the excavation of the valleys by river-action. Similar old Post-glacial gravels are also present, but less extensively, in eastern Norfolk, where they rest on the denuded surfaces of the Upper and Middle Glacial formations; large sheets of them capping the former at Poringland, and the latter at Mousehold Heath.

That, in addition to these older gravels, sheets of a newer gravel, more or less concealed by the alluvium, occupy the bottoms of most of the river-valleys. This newer gravel they consider may be the deposits of the rivers during the Post-Glacial period, and after the valleys had been formed by tidal action.

The sequence of the beds, omitting the Post-Glacial, may be summed up as follows, the beds being taken in descending order :—

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| 1. The Upper Glacial, or true Boulder-clay, of the East of England | } Part of the
Glacial
Series. |
| 2. The Middle Glacial sands and gravels | |
| 3. The Contorted Drift, beginning as a thin bed in the North-east of Suffolk, and thickening out towards the Norfolk coast | |
| 4. The Pebbly sands and Pebble beds. | } True Upper
Crag Series. |
| 5. The Chillesford Clay | |
| 6. Sands containing the Chillesford <i>shell-bed</i> , or <i>Crag</i> of Chillesford, Sudbourn Church Walks, Easton Cliff, and Aldeby, and Upper bed of Bramerton | |
| 7. The Red and Fluvio-marine Crag | |

The Weybourn sand (A), the Cromer Till (B), and the indenting sand (C), (which with the contorted drift make up the Lower Glacial formation), come in below the bed No. 3, which spreads over them and over No. 4; but as they are absent where No. 4 is present they, as before explained, may either represent No. 4, or No. 4 may be only the uppermost member of the true Crag series.

In South-east Suffolk No. 2 rests on 5, 6, or 7, but most frequently on No. 7; Nos. 5 and 6 having been much denuded prior to the deposit of No. 2.

REVIEWS.

I.—A JOURNEY IN BRAZIL. By Professor and Mrs. LOUIS AGASSIZ. Boston: Ticknor and Fields. London: Trübner and Co., 80 Paternoster Row. 1868. 8vo. pp. 540, with 20 woodcut engravings.

“**T**O Mr. Nathaniel Thayer, the friend who made it possible to give this journey the character of a scientific expedition, the

¹ In the small map of the Glacial beds of the east of England, printed by one of the authors for private circulation in 1865, the centre of Norfolk, where these Post-glacial sands and gravels so extensively occur, was represented as principally occupied by the sands and gravels of the Middle Glacial series. This error, which the prosecution of their work has detected, the authors desire to call to notice.