Boswell, Percy George
Hamnall
The geology of the
country around Felixstowe &
Ipswich
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BY

P. G. H. BOSWELL, D.Sc., F.G.S., and
I. S. DOUBLE, F.G.S.

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A CLASSIFIED INDEX


This useful work of reference contains:—1. Alphabetical List of Papers etc., under Authors' names. 2. Subject Index. 3. Index to the Excursions. 4. Chronological List of the Longer Excursions.

AN INDEX

THE GEOLOGY OF THE COUNTRY AROUND FELIXSTOWE AND IPSWICH.

By P. G. H. BOSWELL, D.Sc., F.G.S., and I. S. DOUBLE, F.G.S.

Plates I—3.

SECTION I. INTRODUCTION.

THE area to be visited by the Association at Whitsuntide and described in this pamphlet constitutes the north-eastern portion of the London Basin and comprises those parts of south-eastern Suffolk and north-eastern Essex lying south of the R. Alde, north of the R. Colne, and east of the R. Brett. It thus includes the Suffolk and Essex coastline from Aldeburgh to Walton-on-the-Naze.

Throughout the greater part of geological time, East Anglia appears to have been a land area, and the key to its Tertiary geological history lies in its condition of instability during Cretaceous and post-Cretaceous times.

Older Palaeozoic rocks are reached in many borings at the moderate depth of about 1,000 ft. If the records of the borings made at Lowestoft, Culford (near Bury St. Edmunds), Stutton, Harwich and Weeley are combined, an idealised vertical section such as fig. 1 can be drawn. The Palaeozoic rocks are slates and mudstones of Cambrian (?), Ordovician (?) and Silurian (?) age, the few fossils found being of little determinative value. These rocks are overlain by Gault in south-eastern Suffolk and north-eastern Essex and by Lower Greensand in northern and north-eastern Suffolk. The Old Red

FIG. I.—IDEAL VERTICAL SECTION SHOWING THE GEOLOGICAL SUCCESSION IN EAST ANGLIA.

Scale: 500 feet to 1 inch.

The breaks in the succession are not drawn to scale. They would, of course, be much greater.

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Sandstone, later Palæozoic, Trias, Jurassic and early Cretaceous are absent, and probably were never deposited. A considerable thickness (about 1,000 ft.) of Chalk succeeds the Gault and Upper Greensand, but only the Upper Chalk, which forms the basement-bed of the district, crops out in the valleys.

By plotting the outcrops of the Chalk-zones and later deposits in this portion of the London Basin, it becomes clear that the general structure is that of an anticline with its axis running N.W.—S.E., and pitching beneath the sea in the neighbourhood of the joint estuary of the Stour and Orwell. The post-Cretaceous deposits thicken on each side of this axis as we travel north-eastwards or south-westwards. As will be seen from a section (fig. 2) across the area, this thickening is due not only to erosion on the crest of the anticline, but also to subsidence and

---

**Fig. 2.—Section across the North-West and South-East Axis of Instability in East Anglia.**

Vertical scale: 1 inch = 1000 feet.

- **a** = Change of strike of Chalk zones (pre-Eocene folding).
- **b** = Change of strike of Chalk surface-contours (pre-Eocene and Eocene denudation).
- **c** = Anticlinal axis shown by the isopachytes of the Lower London Tertiaries.
- **d** = Anticlinal axis shown by the isopachytes of the London Clay.
- **e** = Anticlinal axis of the Pliocene deposits (probably a synclinal axis in Miocene times, as indicated by the consequent River Gipping [Orwell] and river capture in the Stour and Deben).
- **f** = Position of maximum post-Glacial rejuvenation of the river systems, due to uplift.

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deposition on its flanks. The Chalk itself maintains practically the same thickness; it therefore appears to have been bent over the knee of the Palaeozoic floor. The surface of the latter slopes away in both directions from the anticlinal axis where the strike of the Chalk changes from W.S.W.—E.N.E. to S.—N.

When the anticlinal axis is plotted for the Chalk (as indicated by the outcrops of the zones _M. cor-anguinum_ to _B. mucronata_) and for the various Tertiary deposits by using isopachytes (2, 547) and the crest-line of the top of the Chalk as shown by the contours of the pre-Eocene and Eocene surface of denudation, it is found that the anticlinal axis was unstable and that movement took place about it at intervals during Tertiary times. Moreover, the axis itself changed position, travelling north-easterwards as indicated in fig. 2, but maintaining the same N.W.—S.E. direction. The anticlinal axis for the Chalk-zones, if projected, would reach the coast near the estuary of the Blackwater, the crest-line for the pre-Eocene Chalk surface about 24 miles farther N.E. at the Stour estuary, the axis of minimum thickness and change of strike of the Lower London Tertiaries about four miles farther N.E. at Felixstowe, whilst that of the London Clay would be found still farther N.E. at the mouth of the Deben (see fig. 2).

We thus have evidence of an earth-wave which advanced from Mid-Essex on to the area under which the Palaeozoic platform is at no great depth, and it seems to have travelled no farther north-easterwards after Miocene times. On the contrary, it appears to have been reflected, for the axis of change of strike of the Pliocene deposits lies about 8 miles S.W., approximately along the line of the Orwell estuary. If the river-systems of the district were inaugurated in the Miocene age, as seems probable on other grounds (see Section VI.) the topographic crest-line would have lain between the R. Deben and the R. Alde, and would have met the present coast near Orford. The Gipping-Orwell is the only true dip-stream, and some amount of capture has taken place inwards towards it on both the north-east in the R. Deben system and on the south-west in the R. Stour system. The first-named system would, therefore, mark the axis of the Miocene trough. As previously noted, it became the crest in Pliocene times. Finally, if the rejuvenation of the existing rivers of Suffolk and Essex (due to post-glacial uplift) is investigated, it is found that a maximum rejuvenation occurs in the R. Stour, the crest of the wave having thus continued its south-westerly movement until recent times.

The rippling to which Essex and Suffolk were thus subjected was only the marginal phase of the earth-movements which folded the Weald and the London Basin, and which, in turn, to use Prof. Grenville A. J. Cole's metaphor, were the outermost ripples

* The numbers in parentheses refer to the bibliography at the end.
Fig. 3.—General Section across the Gipping (Orwell) Valley at Ipswich, showing the buried channel.

1. Upper Chalk.
2. Lower London Tertiaries: Thanet Sands, etc., at the base; Reading Beds; Pebble-Bed.
4. Red Crag.
5. Glacial Sand and Gravel.
7. Loam and brick-earth.
8. Glacioluvial Gravels.
10. Alluvium.

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of the great Alpine storm. But the fact that the movement in the London Basin was confined on the south by the thick and rigid synclinal mass of Mesozoic sediments under the Weald, led to its expansion towards the north-east, where, after breaking over the knee (of Charnoid trend) of the Palæozoic floor, it escaped and was dissipated in the broad area of the present North Sea. In this manner the asymmetrical shape of the London-Belgian Basin seems to have arisen.

The general anticlinal movement outlined above was subjected to some interference by the tilting movements of Pliocene times mentioned in Section IV., and by the subsequent Pleistocene and post-Pleistocene upheavals and subsidences.

GEOLOGICAL FORMATIONS.

The beds which occur at the surface in the area are shown in the following table (see also fig. 3):

<table>
<thead>
<tr>
<th>Era</th>
<th>Beds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recent</td>
<td>Blown Sand</td>
</tr>
<tr>
<td></td>
<td>Shingle</td>
</tr>
<tr>
<td>Post-glacial</td>
<td>Gravels, brickearths and peat-beds</td>
</tr>
<tr>
<td></td>
<td>Brickearths and gravels</td>
</tr>
<tr>
<td>Glacial</td>
<td>Boulder Clay</td>
</tr>
<tr>
<td></td>
<td>Gravel and sand</td>
</tr>
<tr>
<td>Pliocene and</td>
<td>Chillesford Beds</td>
</tr>
<tr>
<td>Pre-Pliocene (?)</td>
<td>Red Crag</td>
</tr>
<tr>
<td></td>
<td>Coralline Crag and Box-stones</td>
</tr>
<tr>
<td></td>
<td>London Clay</td>
</tr>
<tr>
<td>Eocene</td>
<td>Reading Beds</td>
</tr>
<tr>
<td></td>
<td>Thanet Beds</td>
</tr>
<tr>
<td>Cretaceous</td>
<td>Upper Chalk</td>
</tr>
</tbody>
</table>

P. G. H. B.

SECTION II. CRETACEOUS.

The Upper Chalk underlies the whole of the area under consideration, but it is only exposed in the larger valleys. Resting unconformably on it are the Lower London Tertiaries (Section III., p. 8). The outcrop strikes N. and S. through North Suffolk, but it turns and strikes just S. of W. about a line running approximately along the R. Orwell. The dip is very slight, being about 16 ft. to the mile, but this is greater than the slope of the surface on the west of the junction with the Eocene, so that successive zones are exposed from W. to E. But the pre-Eocene and Eocene surface of denudation, which is revealed by constructing a contoured map from the records of wells and borings, has a steeper gradient than has the Chalk itself, so that lower zones are found to underlie the Tertiary Beds from W. to E. (2, 544) as indicated in fig. 4.

The Upper Chalk is a very soft, white, amorphous rock. It is well jointed and contains scanty layers of flints. These usually have a thin white cortex, and are black and fresh inside.
They are very brittle, breaking with a splintery fracture. Occasional marcasite nodules are found. When the surface of the Chalk is uncovered it is seen to be somewhat eroded and worn. Pipes are rarely seen, and are usually very short, though Mr. G. Slater has described one, seen at Claydon, 57 ft. in depth (16, 192). This section has since been destroyed by falls.

Exposures are plentiful in the Gipping Valley, even though many of the pits are now little used. In the Deben Valley it is doubtful if any Chalk is now exposed; in any case, the possibilities of fossil collecting have always been slight. In the Brett Valley there are moderately good sections showing, whilst as far west as Sudbury the exposures are well worth visiting (1, 21).

In the Gipping Valley we have evidence of two zones. In Coe’s pit, Bramford, 1 1/4 ml. N. of the Church, about 100 ft. of chalk is exposed (details of section, p. 8). Near the top *Belemnitella mucronata* may be found, and at about 50 ft. down, large specimens of *Echinocorys scutatus*. Dr. Rowe considers this form to be characteristic of the base of *B. mucronata* zone.

![Diagram](https://example.com/diagram.png)

**Fig. 4.—Section across Suffolk, showing the Chalk Zones and their bevelling by Eocene deposits.**

**Vertical scale:** 2000 feet = 1 inch.


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The lower part of the pit yields *Actinocamax granulatus*, *A. quadratus* and *A. verus*. At Claydon, in a large quarry on the main road, S.S.W. of Claydon Church, *B. mucronata* and *E. scutatus* were found 15 ft. from the top, while Dr. Rowe found *A. granulatus* within 3 ft. of the top. *A. quadratus* and *A. verus* could be obtained here during 1905 to 1908 from the bottom of the pit; now the section is largely covered by talus. *Cardiaster pillula*, and *Rhynchoella limbata* have also been recorded. In both these pits the belemnites are curious, for some show *granulatus* guards with *quadratus* cavities (1, 22). Pits at Baylham, Blakenham, Needham and Barking confirm the position of the two zones, though in all cases fossils are rare.
Fig. 5.—Diagrammatic section showing the lateral transgression of the Chalk zones in East Anglia by Eocene and Pliocene deposits (the zonal dips are diagrammatic).

Vertical scale: 1000 feet = 1 inch.

M.ca. = Micraster cor-anguinum; U = Uintacrinus; Mar. = Marsupites;
A.q. = Actinocamax quadratus; B.m. = Belemnites mucronata; O.l. = Ostrea lunata.

Reproduced by permission of the Council of the Geological Society of London.
The overlapping of the zones of *B. mucronata* and *A. quadratus* has also been recorded in the Isle of Wight.*

In the Brett Valley, *A. quadratus* was found in the pit ¼ mile S.E. of Chelsworth Church, and *Marsupites* in the pit at Back Lane, Monk’s Eleigh. *Uintacrinus* has been recorded from Sudbury.

**SECTION III. EOCENE.**

**Thanet Beds.**

The sequence as given in the table (p. 5) was established by Mr. Whitaker. The correlation of the Thanet Beds with those of the south-eastern portion of the London Basin was based on lithology and stratigraphical position.

The junction with the Chalk is seldom exposed, but in the few cases to be noted the Chalk-surface is somewhat irregular. Usually green-coated flints, some of which are worn and rolled, others broken with green-stained surfaces, are seen resting on it in a matrix of green clay. Some of the flints are curiously pitted on their lower surfaces as if some boring organism had made abortive attempts to penetrate (2, 539). In Norfolk and N.W. Suffolk, the boundary between the Eocene and the Cretaceous runs approximately parallel to the zonal outcrops of the latter, but from where the Chalk turns and strikes south-westwards (p. 5) the Eocene rests successively on lower zones. Thus in the lower part of the Gipping Valley it rests on *B. mucronata* chalk (Bramford), in the upper and western part on *A. quadratus* (Blakenham), whilst at Sudbury Thanet Beds rest on the *Uintacrinus* sub-zone of the *Marsupites* zone. Thus before the deposition of the Eocene of the district some hundreds of feet of Chalk must have been removed (see fig. 5). The bed of green-coated flints has many of the characters of a basal conglomerate.

The Thanet Beds are usually greenish or grey sands and clays, though just west of the area at Sudbury there is a large development of pink sands. True clays are uncommon, the usual facies being sandy. Except for casts of foraminifera in glauconite the beds have not proved fossiliferous.

Exposures are few, many of those noted in the Survey Memoirs now being overgrown, but two good sections are still visible in the Gipping Valley. At Coe’s Pit, Bramford (Plate ra), which is largely worked for chalk but at which some of the overburden (callow) is used for economic purposes, the complete section is as follows:

<table>
<thead>
<tr>
<th>Glacial Drift.</th>
<th>Gravel and sand, current-bedded, up to 20 feet resting evenly upon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crag.</td>
<td>Buff, and brown sand, with ferruginous layers; at the base a gravelly layer 16 feet</td>
</tr>
</tbody>
</table>


PLATE 1.

A.—Section in a Chalk-Pit (Coe’s) at Bramford, near Ipswich.

B.—Section in Eocene Beds at Messrs. Bolton & Co.’s Brickyard, Ipswich, showing unusual shelly condition of the Pebble-Bed.

Photo by G. Bellchambers, Ipswich.

Photo by P. G. H. Boswell.

To face p. 8.
Reading Beds. Whitish and reddish sharp sand, with lenticles of clay . . . . . . . . . . 16 feet

Thanet Beds. Olive-green and blue-green clay, reddish brown and grey clay; olive brown sandy loam; green-coated, pitted and chipped flints . . . . . . . . . . 7-8 feet

Chalk. White, wedge-bedded, B. mucronata-zone . . 100 feet

The gravelly layer at the base of the Crag seems to have been formed by the breaking-up of the pebble-bed which usually lies below the London Clay on the shore of the Crag Sea. The bed consists largely of black flint pebbles, concretionary "coprolites" and ironstone nodules. The Reading Sands are often highly stained by percolating waters and are sometimes changed in character by the deposition of iron oxide.

In the brickyard near by, a small chalk-pit shows a very similar section to that described above, from the Chalk to the Reading Beds, but the succession is continued in the brickyard as follows:

- Glacial Drift. Coarse whitish clay and sand . . . . . . 8 feet
- Crag. Fine sand with ferruginous layers and gravel 8 feet
- London Clay. Brown and grey clay and loam . . . . . . . . 20 feet
- Reading Beds. Pebble-bed, sand and black flints . . . . . . . . 3/4-1 foot

In the uppermost part of the Thanet Beds, a small percentage of relatively large grains are found. These consist of quartz, flint, chert, etc., and have their edges, and in some cases all their surfaces, rounded and polished.

Thanet Beds are also exposed in the old disused chalk quarry at Claydon (p. 6), while traces of the basal green bed may be seen on the top of the Chalk at Blakenham and in the disturbed strata at Hazel Wood, near Bramford.

From the character of the deposits, it is evident they were laid down in moderately deep water, with only feeble currents. Nowhere is there evidence of shallow-water conditions shown by rolled flints and gravels. The occurrence of the larger polished grains may be due to aeolian action with re-assortment in water.

The heavy detrital minerals occur as small angular grains with an average diameter of 0.04 mm. Flakes of muscovite, however, are much larger, being about 0.15 mm. in diameter. Some of the minerals recognised are spinel, garnet, magnetite, rutile, zircon, apatite, tourmaline, ilmenite, staurolite, biotite, muscovite, epidote, green and brown hornblende, actinolite, augite, kyanite, glauconite, limonite, pyrite and pyrolusite. The abundance of hornblende in places is remarkable, as is also the rarer occurrence of augite. Garnet, which occurs in colourless angular grains, is not abundant. Glauconite gives the green colour to the deposits and its presence is suggestive of marine reducing conditions (2, 575).
Reading Beds.

The Reading Beds have a wider distribution than the Thanet Beds, but they show more variation in character. They consist of buff and yellow sands which often contain lenticular masses of plastic clay, and of brightly-coloured mottled clays. The junction with the Thanet Beds is often difficult to determine, but everywhere appears to be conformable.

The sands are fine-grained, and are often current-bedded. Pebbles of clay are sometimes included in them as well as the large lenticles mentioned above. The mottled character of the clays, together with the absence of fossils, suggests that the strata were laid down under fluvial conditions.

Sections showing Reading Beds have been mentioned previously in connection with the Thanet Beds (pp. 8 and 9), but it is to be noted that the latter are found further to the west than the former. At Whitton Leys, 1 ml. S.W. of Whittom Church, the current-bedded sands and the Pebble-bed underlying the London Clay may still be seen, much as they were when recorded by Prestwich in 1850 (16, 272). The section in Messrs. A. Bolton & Co.'s brickyard, just N. of the Norwich Road, Ipswich, showed the following succession in 1916:

Drift. | Fine current-bedded sands, gravels and | Thickness.  
--- | --- | ---  
| Chalky Boulder Clay | 1 to 30 feet  
London Clay. | Glacially disturbed, sheared and puckered clay | 18 feet  
| Blue and brown stiff-bedded clay | 8 feet  
| Basement-bed, brown laminated clay | 2 feet  
| Buff and grey sand | 1 to 2 feet  
| Pebble-bed | ½ to 1 foot  
Reading Beds. | Fine whitish and buff sands | 6 feet  

Evidence of contemporaneous erosion is frequently to be found in the upper part of the Reading Beds.

Adjoining the R. Orwell, and a quarter of a mile S.W. of Greenwich Farm, is a comparatively new exposure, where the clays are worked for brickmaking by Messrs. Gardiner & Co. It shows

London Clay. | Brown clay—the lower part sandy | 3 feet  
Reading Beds. | (e) Brown, reddish and grey mottled clay | 3 feet  
| (d) Buff-coloured sand with blocks of sandstone | 2 feet  
| (c) Buff-coloured, pink, and grey loam and sand | 3 feet  
| (b) Dark grey clay, with pebbles | 4 feet  
| (a) Pale green and scarlet mottled clay | 5 feet  

Bed (d) in this section is worthy of note, for in it may be seen blocks of sandstone in the course of formation. Mr. Whitaker noticed a similar occurrence in the river cliff.

On the other side of the river at Wherstead Brickyard, ¼ ml. S.W. of the church, Reading Beds are shown at the base of the section, but the larger part is in London Clay.

In the Brett Valley, unfortunately, there are now no sections showing, though in the various memoirs of the Geological Survey Mr. Whitaker gave details and useful notes of many.
Scattered throughout the district are large boulders of hardened sandstone—the Sarsens or Greywethers. Their mineral constitution is the same as that of the Reading Sands, but the cementing material varies slightly in different specimens. The constitution and distribution in a belt approximately parallel to the Eocene outcrop, coupled with the fact of the apparent formation of similar blocks at Gardiner's Pit (p. 10), point to their derivation from the Reading Sands (2, 573).

The heavy detrital minerals are much larger than those of the Thanet Beds and have an average diameter of 0.12 mm. Most of these listed on page 9 occur, but biotite, hornblende, pyroxene and epidote are very rare, as is also muscovite. Large well-shaped crystals of tourmaline and large grains of staurolite and kyanite are abundant. Andalusite, corundum and glaucohane have been found.

**London Clay and Pebble-Bed.**

A black pebble-bed lying between the Reading Beds and the London Clay is very persistent throughout the area. Occasionally associated with the pebbles is a bed of grey sand which sometimes contains very fragile shells (see Plate 1B). These are most difficult to secure whole, and have so far proved of no correlative value.

From Messrs. Bolton and Co.'s pit (p. 10) the following have been obtained: *Astarte rugata, A. donacina, A. tenera, Cardium sp., Corbula morrisi, Cytherea sp., Ostrea sp., Panopea sp., Pectunculus sp., Aporrhais sp., Natica labellata, Natica sp., teeth of Odontaspis elegans, O. macrota, O. cuspidata, Lamna vincenti;* and teleostean vertebrae (12, 566. 18, 453). The assemblage is of a shallow-water marine facies.

The pebbles are usually of rounded black flint with at times an admixture of vein-quartz and clay-balls. The pebble-bed appears to represent a shallowing of the sea after Reading times, just previous to the long subsidence accompanying the formation of the London Clay.

Only the basement-beds of the London Clay occur in the district. They are fairly uniform in character, being usually a brown sandy clay, overlying blue or grey clay with bands of septaria and cement-stone. Drifted material is common, but at present only a few fragile fragments of shells and casts of fossils in marcasite or cement-stone have been recorded. Among these are *Pisania sp., Natica labellata, Natica sp., Astarte sp., Cyprina cf. morrisi, Modiola undulaia.* This is again a shallow-water marine assemblage, resembling that of the pebble-bed described above.

Sections of both the clay and the pebble-bed are frequently exposed and include those already described under Thanet and Reading Beds.

The deposit is very uniform throughout the district. Occasional stranded tree-trunks with *Modiola* attached support the
view that it was laid down under deltaic conditions. The heavy
detrital minerals are rather like those of the Thanet Beds
but are somewhat larger, having an average diameter of 0.08
mm. In places, zircon and ilmenite are very abundant. Tour-
maline and kyanite are much less abundant than in the Reading
Beds. Staurolite is also less common. Hornblende is the
dominant ferromagnesian mineral, and muscovite, 0.2 mm. in
diameter, and biotite occur more frequently than in the Reading
Beds. Although the various Eocene deposits differ from one
another in the details of their mineralogical constitution, they
conform to a general type which differs materially from that
which characterizes the overlying Pliocene deposits (p. 16).

SECTION IV. PRE-PLIOCENE AND PLIOCENE.
The interval between the deposition of the London Clay and
the Pliocene "Crags" must have been considerable; the
Miocene and Oligocene as found on the other side of the North
Sea are absent. The Chalk, with the softer sediments on its
flanks, was uplifted and denuded, and it is probable that the
present drainage was inaugurated during this period. Gentle
subsidence followed which began in the south and passed as a
ripple northwards. In the succession of bays thus formed a
warm sea left the record of its fauna in the shelly sands, but
as the movement proceeded the south was gradually uplifted and
communication in that direction closed, whilst the way was opened
for colder northern waters to enter with a characteristic boreal
fauna. Thus the older Crags are marked by the predominance
of southern forms and the younger by northern.

In the pamphlet written for the excursion of the Association
to East Anglia in 1902 (7) and in the Jubilee Volume of the
Association (8), Mr. F. W. Harmer has given a very full account
of the various horizons and of their geological history. Little
need be added here, except with regard to the specific exposures
it is intended to visit.

Mr. Harmer's classification with the corresponding Continental equivalents as it applies to the area to be visited is given
below:

<table>
<thead>
<tr>
<th>Divisions</th>
<th>Localities</th>
<th>Continental Equivalents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Icenian</td>
<td>Chillesford Beds—Chillesford</td>
<td></td>
</tr>
<tr>
<td>Butleyan</td>
<td>Red Crag—Butley, Bawdsey, etc.</td>
<td></td>
</tr>
<tr>
<td>Newbournian</td>
<td>&quot;—Newbourn, Sutton, etc.</td>
<td>Amstelien</td>
</tr>
<tr>
<td>Waltonian</td>
<td>&quot;—Beaumont and Little Oakley</td>
<td>Poederlien</td>
</tr>
<tr>
<td></td>
<td>&quot;—Walton-on-the-Naze</td>
<td>Scaldisien</td>
</tr>
<tr>
<td>Gedgravian</td>
<td>Coralline Crag—Orford, Sudbourne, etc.</td>
<td>Casterlien</td>
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PRE-PLIOCENE.

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The Box-Stones.

In places at the base of the Crags, a bed of rounded concretionary sandy pebbles is found. Associated with the rolled and waterworn stones are the so-called "coprolites"—phosphatic nodules, derived London Clay fossils, and phosphatised bones of cetaceans and mammals—and even igneous erratics (13, 6). From the occurrence of casts of fossils in the sandy concretions they were termed by the old coprolite workers "boxes" or "box-stones."

A full list of the contained fossils, compiled from various sources, has been published by Mr. A. Bell (13, 7). The assemblage, though somewhat of the Lenham type, is not identical, and recent workers agree that the Box-stone fauna is pre-Pliocene in age.*

The mollusca include the following characteristic forms:—
Conus dijardini, Nassa conglobata, Voluta auris-leporis, Isocardia lumulata.

In this connection it is interesting to note that the mineral assemblage is generally like that of the Crags (6, 259); thus while the fauna shows the Box-stone bed to be older than Pliocene yet the conditions of drainage during its formation were probably similar to those of the succeeding epoch.

The Coralline Crag.

The Coralline Crag is always associated with Red Crag. The main mass from Gedgrave near Orford, to Aldeburgh, is elliptical in form with an alignment roughly N.N.E. to S.S.W., that is, parallel to the present coastline. It frequently appears to consist of two divisions, the upper a hard indurated sand and the lower a softer shelly crag. This apparent division is found throughout the whole extent of the Crag, and is caused by the decalcification of the upper part by percolating water and the deposition of iron oxide and secondary calcium carbonate. In the upper part, or "rock-bed," the only shells that are preserved are those composed of calcite, whilst those composed of aragonite are represented only by casts (14, 497). The sands are frequently current-bedded, often at a high angle, and much drifted material is present. Layers of broken shells and of single valves are common. Very rarely are both valves found in contact. However, polyzoa occur in the position of growth and evidently assisted in arresting the comminuted material in which they are now embedded. Thus the Coralline Crag was formed as reefs or sand-banks in the then existing Crag sea, not very far from land but at some distance from any river discharging into it. The polyzoa flourished when any change of current diverted the drifting material and died when choked by sediment.

* Mr. R. B. Newton regards it as Miocene.
The fauna is mainly of a southern character and is closely related to that of the Waltonian Crag. Among the characteristic forms may be mentioned:—

*Anomia ephippium, Ostrea cochlear, Pecten tigrinus, P. gerardi, Pectunculus glycimeris, Cardita senilis, C. scalaris, Astarte incerta, A. omalii, A. basterolii, Scalaria foliacea, Terebratula grandis, Cyprina islandica, C. rustica.*

In the bryozoan rock-bed are found *Theonoa aurantium, Alveolaria semiovata, Echinus woodwardi, Ostrea* and *Pecten.*

The bryozoan rock-bed is well seen in the large pit near Orford Castle, and the shelly sands (see Plate 2A) in Sudbourne Park (7, 428). At Tattingstone Hall, 4 miles S. of Ipswich, a small exposure of comminuted crag is visible in the farmyard (15, 327).

**THE RED CRAIG.**

The Red Crag, resting unconformably on London Clay and on the flanks of the Coralline masses, extends from Walton-on-the-Naze to Aldeburgh along the coast, and also for some distance inland. The removal of the shells by percolating water sometimes leaves a sand which may or may not be red and ironstained, though most of the Crag sands are of a very rich colour. The tectonic movement which produced the bays or inlets in which the Red Crag was deposited passed from south to north, and thus the successive zones or horizons succeed one another laterally rather than vertically. When the Coralline Crag was formed, there must have been communication with a warm southern sea, for its fauna is predominantly southern. Then a certain amount of uplift took place, with denudation of the soft shelly sands. The presence of the Box-stone bed at the base of both Coralline and Red Crags is most probably due to the fact that the concretions and other debris were much more resistant and remained to become the bottom of the newer Crags.

The Red Crag is strongly current-bedded, often at an angle as high as 30° (see Plate 2B), which indicates a deposit formed against a beach or foreshore. The large quantities of comminuted shell-fragments, the single valves, and the absence of fossils in the position of growth, indicate the drifted character of the remains. Similar drifted banks of shells are being formed on the Dutch coast at the present day.

Many forms occur throughout all the divisions of the Crags, but the predominance of certain species determines the exact age. Mr. Harmer's papers contain many full lists of the species identified and it will be sufficient here to give characteristic fossils likely to be found on the excursion.

The Waltonian Crag is marked by the predominance of southern species, though northern forms are beginning to appear. Characteristic fossils include:—

*Cardium parkinsoni, Dosinia exoleta, Mactra arcuata,
A.—Solution-pipes in shelly Coralline Crag, Sudbourne Park.

B.—Current-bedded Red Crag, with Stalactites of redeposited Calcium Carbonate. Mr. Fred Smith’s Pit, Woodbridge, 1906.

Reproduced by permission of the Council of the Ipswich and District Field Club.

To face p. 14.
Nucula laevigata, Nassa granulata, N. propinquia, N. labiosa, Neptunea contraria, Trochus andansoni, T. subexcavatus, Purpura lapillus (and var. oakleyensis).

Many of these species are now extinct.

Waltonian Crag is to be seen in the cliffs at Walton and Beaumont, and was formerly visible at Little Oakley, near Harwich. The area between the Orwell and Stour has not yet been fully explored, but the deposits show affinities both with the Waltonian and the succeeding Newbournian (15, 329), and contain derived Waltonian forms.

Of the Newbournian Crag, which is found between the Orwell and Deben estuaries, the following species may be considered representative:


Exposures are common, notably at Ipswich, Woodbridge, Newbourne, and Felixstowe. At Sutton a bed of Mytili may sometimes be seen attached to an old shore-line formed of Coralline Crag.

The Butleyan Crag, found north of the Deben estuary to Aldeburgh, contains amongst others the following forms, many of which are northern and living:

Mactra ovalis, M. constricta, Neptunea antiqua, N. contraria, N. despecta, Nucula cobboldiae, Tellina obliqua, T. praetenuis, Cardium angustatum, Natica catena, N. clausa, Scavria grænlandica, Admete viridula, Mytilus edulis.

**THE CHILLESFORD BEDS.**

The Chillesford Beds, consisting of clays and sands, overlie both Red and Norwich Crag, but the latter does not occur in the area to be visited. The outcrop of the Chillesford Beds may be traced in a sinuous curve from Chillesford in the south to Aldeburgh and into Norfolk. It is considered to represent one of the old courses of the Rhine, opening into the sea northwards. Both clay and sand contain much mica, the most probable source of which would be the Ardennes. The clay is usually laminated, grey in colour and plastic, whilst the sands are pale brown and fine-grained. Near Chillesford Church the sand below the clay contains among others the following fossils:

Nucula cobboldiae, N. tenuis, Natica catena, Turritella terebra, Yoldia oblongoides, Y. lanceolata, Cardium edule, C. grænlandicum, Mactra ovalis, Tellina lata, T. obliqua, Mya truncata.
The fauna is thus a boreal one and includes many living species. Many of the lamellibranchs have both valves adherent, but are not specially in the position of growth. The shells are more fragile than those found in the Red Crag.

Examination of the mineral assemblages in the various crags is in progress. Enough has been done, however, to state that the general character is notably different from that of the Eocene, and is a very rich and varied assemblage. Green pyroxene, hornblende, andalusite and epidote are common; large kyanite crystals with inclusions, and deep golden yellow staurolite are dominant; tourmaline occurs in large well-shaped crystals; flakes of mica, of diameter 0.3 mm. are plentiful; whilst large red garnets are extremely abundant. The average diameter of the grains is 0.2 mm.

SECTION V.—THE GLACIAL DEPOSITS.

By far the greater part of the area is covered by glacial deposits, including sands, gravels, breccearts, and clays. Not only is the higher ground covered, but the deposits extend down into the valleys; indeed it is only in the larger valleys and on the coastal belt that the other formations are seen. The older divisions into Lower, Middle, and Upper Glacial can hardly be maintained. The Lower Glacial (Cromer Till and Contorted Drift = North Sea Drift) is nowhere represented in the district (3, 7, 8).

The great stretches of sands and gravels that underlie and fringe the Chalky Boulder Clay may be slightly older in parts than that formation, but are genetically connected with it. The advancing ice would be preceded by floods of water that would carry the detritus out of which the sands and gravels would be laid down. As the ice continued its course it would override them, just as it is seen to do in glaciated regions to-day. Alternation of advance and retreat would result in the interdigitation of the Boulder Clay with the sands and gravels, though in general the clay, representing the finally-deposited material in the retreat, would overlie the others.

The gravels consist very largely of flints of all sizes and colours. Some are comparatively black and fresh, while others are ironstained, broken and battered. Sandstones, quartzites, occasional igneous pebbles, hard chalk and Jurassic limestones and fossils are less abundant. A certain amount of sorting and orderly deposition is sometimes evident.

The sands are clean, there being very little silt or clay present. In colour they are white, grey, or buff, in striking contrast with those of the Crag or of recent age. The grains are sharp and angular, and it is rare that any rounding or polishing can be observed. The detrital mineral assemblage is of a very rich
type as would be expected from the mode of origin (4, 91). Current-bedding is common, and on the whole the deposits are well-graded.

A comparatively new pit on the southern side of Rushmere Road, Ipswich, ½ ml. S.W. of Rushmere Church, is worth noting. It shows the best section of these sands and gravels now existing near Ipswich.

Bolton’s pit (p. 10), also shows good exposures of sand in two channels which are flanked on each side by the London Clay. At its eastern end there is a larger development of sands which pass into Boulder Clay, and in the small pit, now disused, on the eastern side of Henley Road, typical Chalky-Kimmeridgic Boulder Clay has been worked for brick-and-tile making.

Connected with the sands and gravels and also with the overlying clays are the “brickearths.” These are usually finely laminated clays resting in lakelike hollows in the sands or boulder clay. Frequently they are seen to pass into chalky sands and then into boulder clay of the usual type. Most of the exposures noted in the Survey Memoirs are now overgrown, and the sites of the old brick-works converted to other uses. The contorted nature of many of these brickearths led to their being considered as Lower Glacial in age, but stratigraphical evidence is against this (3).

The Boulder Clay itself is of Harmer’s Chalky-Kimmeridgic type (9, pl. 3). It has a matrix of blue, olive-green or grey clay, and contains an abundance of Kimmeridgic detritus, such as shale and septaria. On the west of the Gipping-Stour watershed Oxfordian material increases, but the clays are of the same general type. They are characterized by the abundance of chalk-fragments, both hard and soft; at times the fragments are so abundant that the clay becomes a re-arranged chalk. Amongst the erratics are to be found Lincolnshire Oolite, Liassic fossils (e.g. Gryphaea, Ostrea, Belemnites), hard and soft chalk, grey tabular and black flint, red chalk (Selbornian), Neocomian sandstones (often glauconitic, phosphatic and fossiliferous), quartzites, Scottish granites, dolerites and andesites.

The clay has been much used for brick-making, as on washing it yields a brickearth, precisely similar to the natural occurrences of that material, out of which good white bricks could be made. At Claydon, ¾ml. W.S.W. of the station, it is worked for cement-making. Here it abuts against an eroded surface of Chalk. The material removed from the wash-mills gives good opportunities for examination of the contained erratics. The junction of the clay and Chalk is here interesting, for the latter is seen to be shattered and polished by the grinding of the valley-glacier and also eroded by sub-glacial action. This is not an uncommon feature in the valleys. In many of the pits mentioned in other sections, such as Claydon, p. 6, and Blakenham, p. 9, the top few
feet of chalk is seen to have suffered similarly, whilst the Tertiary deposits, if present, have often been torn, twisted and thrust into new relationships. During the reduction of the hill between the Hadleigh and London Roads, S.W. of the town of Ipswich, for building purposes, and in the widening of the adjacent railway cutting, this was everywhere made apparent (5, 592). Mr. G. Slater carefully measured and mapped the exposures, and a detailed section, painted on glass, illustrating the action of the valley-glacier at that point, is to be seen in the Ipswich Museum.

At Bolton & Co.'s Pit (p. 10) the London Clay has been sheared into distinct planes, in striking contrast with the normal homogeneous deposit (see Plate 3A). Whenever there was a spur in the valley, truncation and disturbance resulted (5).

The usual thickness of the Chalky Boulder Clay is about 100 ft. but the records of well-borings reveal many anomalous thicknesses. Each of the larger valleys, notably the Deben, Gipping, Box and Stour, is found to have a deeper valley in it. The records have been collected and discussed (5). In Ipswich, with its much greater number of borings, both for water and for the dock and its proposed extensions, the course of the channel has been more accurately determined (see fig. 3). It is probable that these channels are analogous with channels cut by sub-glacial streams and which have been termed "Föhrden" in Schleswig-Holstein.*

Overlying the Boulder Clay in places are gravel mounds such as the Creeting Hills, E. of Needham Market, and at Elmswell. They are probably of glacieluvial origin and connected with the retreat of the Chalky Boulder Clay ice. Usually they consist of very irregular and ill-assorted coarse flint gravels, very much battered and iron-stained.

I. S. D.

SECTION VI.—EARLY MAN AND POST-GLACIAL CHANGES.

When full investigation has been made, it will probably be found that the record of post-glacial geology is more fully written in East Anglia than in any other part of Britain. Although the day has passed when Man was considered a product of post-glacial conditions, the evidence of his activities in East Anglia may more fitly be touched upon in this section than in Sections IV. and V.

The dividing line between post-glacial and glacial deposits is just as difficult to place as the equally arbitrary division between Pliocene and Pleistocene.

The "rostro-carinate" and other sub-Crag chipped flints discovered by Mr. J. Reid Moir in the Crag (?) detritus-bed at Messrs. Bolton & Co.'s brickyard (p. 10) and under undisturbed

Plate 3.

A.—Bolton & Co.'s Pit, showing Disturbance of Sands and London Clay.

B—Accretion of Shingle at Landguard Point, Felixstowe.
(See text).

To face p. 18.
Crag at other neighbouring localities have not yet been generally accepted as Man's handiwork. The scrapers, borers, and other types of supposed pre-Chellean implements found by him at two levels in the crag-pit near Foxhall Hall have obtained more general acceptance among archaeologists, including the Abbé Breuil and Mr. M. C. Burkitt. Mr. Moir has also found worked flints, which he claims to be of lower Palæolithic (coup de poing) type in the glacial sands and gravels underlying the Chalky Boulder Clay near Ipswich (e.g., at Bolton & Co.'s pit), and Mousterian implements in the Boulder Clay itself. The subject is one of extraordinary difficulty, for in the brecce-earths overlying the Chalky Boulder Clay of the area (p. 17),—apparently the final legacy of the retreating ice-sheet—are found beautiful implements of Acheulian culture. Moreover, gravels and brick-earths which occur on the valley-slopes and are clearly ancient river-deposits, contain various types of Chellean, Acheulian and Mousterian implements. The problem of the history of Man in this district is thus indissolubly linked with that of the development of the present topography.

When the "solid" geological map of East Anglia is examined, it is found that the form of the river-systems is strikingly related to the "grain" of the country as represented by the Chalk and various Eocene deposits. The Gipping-Orwell system is a simple transverse stream. The Stour of to-day consists of a remarkable series of stretches each about 12 miles long, alternately transverse and longitudinal, with sharp rectangular bends. The Colne corresponds in position with the be-trunked portion of the Upper Stour, and the Deben shows a similar series of stretches related to the strike of the Chalk and Eocene. The coincidence of the transverse and longitudinal directions of the streams with the dip and strike of the rocks, especially as the directions vary with the varying strike round the elbow of south-eastern Suffolk, is so close as to suggest a causal connection. But the actual evidence provided in the valleys themselves is sufficient only to show that the present valleys are post-Pliocene and pre-Upper Glacial. They are excavated in the Crag and older deposits, but were clearly marked topographic features when the ice which laid the Chalky Boulder Clay on the floors and slopes of the valleys took advantage of their existence and modified their outlines. This apparent contradiction in the matter of age is best explained by assigning the inception of the systems to the Miocene period, by the end of which the present topography with its evidence of river-capture was established. The rippling submergence which resulted in the deposition of the shallow-water Pliocene deposits affected only the more seaward portion of the coastal plain, and any Crag material laid down in the valleys themselves must since have been scoured out by glacial floods, with the consequent enlargement of the valleys.
On the retreat of the ice, south-eastern Suffolk and north-eastern Essex were left covered with areas of Boulder Clay and sand and gravel, in the hollows of which, on the plateau as well as in the valleys, lay lakes of icy water originally laden with rock-flour. Anticyclonic conditions prevailed and powerful winds swept from the still ice-bound regions on the north-west over East Anglia. The Boulder Clay and brick earths were rapidly dried and the fine material, akin to the Continental loess and limon, was spread over north-eastern Essex as the superficial "brickearth" (so mapped by the Officers of the Survey), a deposit structureless and without bedding. In north-western Suffolk the blown-sand areas were due to the same cause. More humid conditions followed, and it is probable that the country became heavily forested, the only evidence preserved, however, being that of the buried forests in the estuaries (as in the Orwell) and off the coast (in proximity to the Deben mouth). The present position of these peat-beds at a depth of about 20 feet marks the latest movement of importance in East Anglia. The subsidence which carried them into their present position was probably a general one of which evidence exists round many parts of Britain. In south-eastern Suffolk it drowned the lower courses of the valleys, giving rise to the estuaries of the Colne, Stour, Orwell and Gipping, and arresting the work of the streams. From this check they now seem to be recovering, as a result of slight uplift and consequent rejuvenation, and are once more engaged upon the work of clearing their valleys of débris.

The final stage in the production of the present geography of East Anglia is the coastal modification, of which much is so recent as to be confirmed by historical evidence. The tidal scour southwards in the North Sea tends to bank up shingle on the coast, and to carry it southwards, especially during north-westerly gales. Thus the mouths of small streams are dammed up entirely, and larger rivers are deflected southwards. A notable case of this diversion is yielded by the R. Alde which formerly entered the sea at Aldeburgh. The river now flows southwards behind a shingle spit, which attains its greatest breadth of two miles at Orford; it only succeeds in breaking through the spit 10 miles south of Aldeburgh. The same phenomenon was in course of development at Harwich, where the R. Stour in all probability formerly flowed directly eastwards, north of Landguard Fort, Felixstowe, into the North Sea. Throughout the Middle Ages, and up to 1860, the spit of Landguard Point steadily extended southwards, as shown by various contemporary maps, thus diverting the mouths of the Orwell and Stour estuaries. Commercial considerations then necessitated the intervention of man, and a jetty was built running south-westwards from the side of the spit. Accretion immediately began on the north-
east of it, and scour on the south-western side rapidly diminished the spit and maintained the position of the joint mouth of the estuaries. In the 48 years which elapsed between the building of the jetty and the time at which the photograph was taken there resulted a gain of over a million tons of shingle and 25 acres of land. This accretion is shown in the fore-ground of Plate 3B. the people standing on what was once the old shore-line.

P. G. H. B.

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