Brannam's Clay Pit

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Highlights

Brannam's Clay Pit is one of South-West England's most important Pleistocene sites, providing the best exposures of the enigmatic Fremington Clay, the age and origin of which have been the subject of scientific debate for over 130 years. The material has been interpreted variously as the product of land-based ice, as a glaciolacustrine deposit and as glaciomarine muds. Estimates of its age have varied widely between Oxygen Isotope Stage 16 (pre-Anglian) and the Late Devensian.

Introduction

The Fremington area has long been known for a contentious sequence of deposits which has a major bearing on Pleistocene reconstructions in South-West England. Part of the sequence (often referred to as the Fremington Clay or Till) has been interpreted as the product of a pre-Devensian (Saalian Stage) glaciation, but recent evidence suggests that the deposits may not have been laid down directly by glacier ice and that they are older. The site was noted in an early study by Maw (1864) and since by Ussher (1878), Prestwich (1892), Dewey (1910, 1913), Balchin (1952), Taylor (1956), Zeuner (1959), Mitchell (1960, 1972) and Everard *et al.* (1964). Detailed accounts were provided by Stephens (1966a, 1966b, 1970a, 1974), Wood (1970, 1974), Edmonds (1972), Kidson and Wood (1974), Kidson (1977) and Kidson and Heyworth (1977). Recent excavations were undertaken by Croot (1987), Croot *et al.* (*in* prep.) and Gilbert (in prep.). The site has also been mentioned widely elsewhere (e.g. Waters, 1966b; Stephens, 1961a, 1961b, 1973; Gregory, 1969; Cullingford, 1982; Hunt, 1984; Campbell and Bowen, 1989; Eyles and McCabe, 1989; Bowen, 1994b; Campbell *et al.,* in prep.).

Description

Maw (1864) demonstrated that the Fremington Clay or 'boulder clay' extended in an oval area some 5.6 km long by 0.8 km wide (Figure 7.2), from Lake to Mullinger. Several small outliers of the clay were also noted. (The distribution of the Fremington Clay and related sediments has since been revised by Croot *et al.* (1996), although much of Maw's original mapping still holds good.) The clay reached a maximum thickness of 27 m and was described by Maw as a tough, homogeneous, smooth brown clay with stones towards the top and with blackened wood fragments at the base. Near Bickington the clay overlay a gravel similar to that exposed on the coast at Fremington. A comparable succession was also described by Ussher (1878).

Brannam's Clay Pit [SS 530 316], sometimes known as Higher Gorse Clay Pits, lies off Tew's Lane near Bickington and is located almost centrally in the known extent of the Fremington Clay. The stratigraphic succession exposed in Brannam's Clay Pit over the years has revealed both lateral and vertical variation. However, most authors have recognized a sequence of basal gravel, capped by stoneless clay overlain by stony clay and head over quite wide areas. (Figure 7.3) depicts the sequences described by Stephens (1966a, 1966b, 1970a), Croot (1987) and Croot *et al.* (1996). Stephens' sequence can be summarized thus:

9. Soil

8. Solifluction deposits with frost-cracks

7. Sand

6. Weathered till

5. Fresh till

4. Stoneless clays

3. Sand

2. Fresh till

1. Pebbles (raised beach deposits)

Broadly comparable sequences were described by Edmonds (1972) and Kidson and Wood (1974), although the interpretation of the origin and ages of individual beds has varied considerably. Croot *et al.* (1996) recorded the following sequence in Higher Gorse Clay Pits, within 50 m or so of the sections previously described by Stephens (1970a) and Croot (1987) (Figure 7.3)c:

E. Gravelly sand and clay (head). A matrix-supported deposit with angular and subangular clasts of local bedrock set in a matrix of coarse yellow/brown clay. The deposit is uniformly 1.5 m thick across the exposed section and its contact with unit D is irregular and gradational (Figure 7.3)b. (1.5 m*)

D. Clast-rich weathered clays. The material comprises more than 50% of clasts in a matrix of red clayey silt. Constituent clasts comprise mostly small gravels of lithologies identical to those in unit B. The matrix contains ill-defined and deformed silt-rich horizons. The unit is disrupted by irregular compressional and extensional stress patterns and clasts exhibit no consistent fabric. (1.0 m*)

C. Sand lenses within unit B. This unit comprises irregularly shaped lenses of sand and silt. The deposit consists mainly of medium-grained sand grading into coarse sand and medium silt. Grains are mainly of quartz but some of haematite and magnetite are present, together with clasts of sandstone, mudstone and, especially, lignite. The lenses exhibit no evidence of bedding or grading structures, and their contact with the surrounding clays of unit B is sharp and irregular. The sand bodies have no clearly defined channel form. (2.5 m*)

B. Dark brown clay. Contains occasional sub-rounded clasts and buff-coloured, irregularly spaced silt-rich beds. The proportion of clasts rises from 5% near the base of the unit to *c.* 40% where unit B grades into unit D. Contact between the silt bands and clay matrix is diffuse. Clasts within the unit lack any distinct fabric (orientation or dip) and do not appear to disturb the bedding of clays and silts. All but one of the clasts (sample size > 1500) are derived from bedrock lithologies found within 10 km of the site. The single exception is a cobble-sized, well-striated clast of microdolerite found *c.* 4 m below the surface of unit B. (9.0 m*)

A. Gravels. Comprises gravels in a sandy-silt matrix. The component clasts are dominantly subangular and comprise very locally derived sandstones, siltstones and shales of the Crackington Formation (Prentice, 1960); they exhibit a weak fabric with a north-west to south-east orientation but no discernible dip. (2.0 m*)

(*) denotes maximum bed thickness

Erratics associated with the Fremington Clay were described by Maw (1864), Dewey (1910), Taylor (1956, 1958), Vachell (1963) and M. Arber (1964). Maw (1864) recorded a large boulder of 'basaltic trap' which he believed had originated from the middle of the clay bed (probably unit B; see above). Dewey (1910) recorded boulders of hypersthene andesite and spilite which had apparently been derived from the 'till'; he suggested that the former had originated from the west coast of Scotland, the latter from north Cornwall. Taylor (1956, 1958) recorded boulders of quartz porphyry, quartz dolerite and olivine dolerite from the clay, and additional erratics were recorded by M. Arber (1964). Taylor noted that the erratic recorded by Maw was striated. However, Croot *et al.* (1996) argue that the microdolerite clast from unit B represents the first reported find of an 'unequivocally glacially-transported *in-situ* clast at the Brannam's clay pit site.' (Croot *et al.,* 1996; p. 20). This assertion, however, is strongly refuted by Stephens who cites his own observations and those of the old clay pit foreman, as evidence of in *situ* erratics in the clay (Stephens, pers. comm.).

Edmonds noted that the upper part of the sequence (beds 6–8; Stephens' description) contained numerous rock fragments and pebbles, mainly sandstone and quartzite, but also slate, vein quartz, chert, granite, dolerite and flint. Stephens (1966a, 1970a) recorded that the beds he interpreted as till (his beds 2, 5 and 6) and the stoneless clays (his bed 4) contained pieces of lignite, shell fragments (especially abundant according to Waters (1966b)), erratics and striated stones. Croot *et al.* (1996) record $CaCO_3$ values of between 10% and 20% for units B and D; sand from unit C, surprisingly, has a lower value (5.5%), but contains numerous small (+ 14) to 04)) shell fragments of undetermined species. Units B, C and D contain abundant pollen and spores but no material uniquely of Pleistocene age. Damaged palynomorphs of Mesozoic and Palaeozoic age are also present. Hunt (1984) identified and listed Carboniferous, Jurassic, Cretaceous and Palaeogene palynomorphs in samples from these units. The nannofossil assemblage is dominated by reworked Cretaceous forms (Croot *et al.,* 1996) although Wood (1970) records a varied fauna of foraminifera which he suggests rules out a freshwater origin.

Kidson and Heyworth (1977) recorded laminae from stoneless clays in unit B. Croot *et al.* (1996), however, suggest that original sedimentary structures are only rarely visible even at a microscopic scale.

(Numerous descriptions of the sequence at Brannam's Clay Pit have referred to the Tremington Clay' or 'Till' without reference to specific beds within the sequence. This confusion was recognized by Wood (1970, 1974) and Croot *et al.* (1996) who adopted the term 'Fremington Clay Series' to describe the sequence of clays and stony clays at the site. The term 'Fremington Clay' is retained here to describe the clay and diamicton sequence (units B–D; Croot *et al.,* 1996) without implying specific origins.)

Interpretation

Maw (1864) correlated the gravel beneath the Fremington Clay in the Bickington area with shingle deposits exposed on the coast at Fremington. These had previously been interpreted by De la Beche (1839) as raised beach deposits (Figure 7.2). Maw noted the close correspondence in height of the gravel beds at some 10.6 m above HWM. He demonstrated the relationship of the clay and gravel deposits over a wide area (between Bickington and exposures on the south side of the Taw) — a practice followed by later workers including Mitchell (1960) and Stephens (1966a). However, he contrasted the uncemented and unstratified gravels at Bickington and Fremington with the layered and cemented raised beach sands and gravels at Hope's Nose (Torquay) and Croyde Bay which, in addition, contained abundant marine shell fragments. He entertained the possibility, therefore, that the gravels at Bickington were related more appropriately to the overlying clays which he considered, albeit tentatively, were glacial in origin. He argued that erratics at the base of the Croyde raised beach deposit and towards the top of the Fremington Clay were probably of the same age, and that the Fremington gravels were therefore older than the raised beach at Croyde, being … separated by at least the interval in which most, if not all, of the Fremington clay-bed was deposited.' (Maw, 1864; p. 450). Ussher (1878) regarded the Fremington gravels and the local raised beaches as the same age (unspecified) and of estuarine origin.

Many subsequent authors (e.g. Prestwich, 1892; Dewey, 1910, 1913; Taylor, 1956, 1958; Vachell, 1963; M. Arber, 1964) established the petrology and sources of erratics associated with the Fremington Clay. Most of the boulders appear to have been derived from relatively local sources in Devon and Cornwall (Dewey, 1910, 1913; Taylor, 1956; M. Arber, 1964). Some, however, had more distant origins, including the hypersthene andesite recorded by Dewey (1910) which was believed to have originated from the west coast of Scotland. The precise stratigraphic context of many of the early finds, however, is doubtful, although Maw (1864), Dewey (1910) and M. Arber (1964) presented evidence to suggest that some of the larger erratics had been derived from within the Fremington Clay (unit B) itself. Although such evidence has been used to support a glacial origin for the bed (M. Arber, 1964), others have been more cautious. Taylor (1956) suggested that the erratics may have been transported by floating ice, and Dewey (1913) suggested that the clay had been deposited … under such conditions as would permit large erratic boulders to be dropped in it.' (Dewey, 1913; p. 155).

The Fremington Clay was also briefly referred to by Balchin (1952) who regarded it as an alluvial infilling of reworked Keuper Marl.

The Fremington Clay was next referred to in regional stratigraphic correlations by Zeuner (1959) and Mitchell (1960). Zeuner regarded the clay as a 'bottom-moraine' of an ice sheet from the Irish Sea, which had penetrated inland on the southern shore of the Bristol Channel. Mitchell (1960) argued that the raised beaches of the area (at Fremington and Saunton) lay stratigraphically beneath the Fremington Clay, which he too regarded as a till, but of Gipping (Saalian) age (Figure 7.2). He correlated the 'Fremington Till' with the Ballycroneen Till of Ireland, and assigned the raised beaches of the area to the Hoxnian Stage, and not to the last (Ipswichian) interglacial as suggested by Zenner (1959).

Mitchell's (1960) proposal for a Pleistocene chronology in north Devon was also upheld by Stephens (1961a, 1961b, 1966a, 1966b, 1970a, 1973). From evidence at Brannam's Clay Pit, Stephens argued that the pebbly gravels (his bed 1; unit A) could be correlated with raised beach deposits exposed at the coast; according to him, they contained well-rounded clasts and occurred at approximately the same height. These proposed Hoxnian-age marine sediments were overlain by a sequence of tills (his beds 2, 5 and 6) and lake clays (bed 4), the diagnostic characteristics of which (including pebble lithology and orientation, texture, carbonate, shell and lignite content) indicated derivation from the Irish Sea Basin. Stephens correlated these beds with the Ballycroneen Till (Eastern General Till) of Eire of proposed Saalian age (cf. Mitchell, 1960). During the Ipswichian the surface of the till was chemically weathered (accounting for his bed 6), and during periglacial conditions in the Devensian the upper layers of the proposed till were soliflucted and mixed with locally derived head (bed 8). Frost-cracks were also formed during this periglacial phase (Stephens, 1966a, 1970a).

In marked contrast, Edmonds (1972) argued that the proposed raised beach deposits exposed around Fremington Quay were Ipswichian in age but were dissimilar to the gravels spasmodically exposed in the bottom of Brannam's Clay Pit (cf. Bowen, 1969); he thereby discounted Mitchell's and Stephens' stratigraphical correlations. He argued, however, that the overlying tills and lake clays were of Wolstonian (Saalian) age, suggesting that Wolstonian ice had moved south across the Irish Sea to the north Devon coastline, and in the process deposited erratics on Lundy (Mitchell, 1968). This ice was believed to have advanced across the Fremington area depositing till (bed 2 of Stephens), and then receded to an unknown position, but probably near Fremington (Figure 7A). The ice front dammed surface waters, forming a lake basin to the east. The fine-grained sediments of the Fremington Clay (Stephens' bed 4; lower part of unit B) were believed to have been deposited in these relatively still lake waters (Edmonds, 1972). It was envisaged that the ice then readvanced perhaps as far as Barnstaple to deposit a further till (Stephens' beds 5 and 6) (Edmonds, 1972).

Wood (1970, 1974) and Kidson and Wood (1974) reinvestigated the Pleistocene deposits of the Barnstaple Bay area, and particularly those in the vicinity of Fremington, using boreholes and geophysical techniques. They demonstrated that the gravel (unit A) was distinctive in terms of clast lithology and roundness, and particle-size distribution, and that it was not therefore associated with the raised beach deposits exposed at the coast (e.g. at Fremington Quay). Instead, they suggested that the gravel at Brannam's Clay Pit was a glaciofluvial sediment — perhaps formed by the same ice lobe which deposited the overlying tills and clay (Kidson and Wood, 1974). They suggested that erratics in the proposed glacial beds at Brannam's Clay Pit could be correlated with the giant erratics at Croyde and Saunton — which rest on a shore platform and which are associated with raised beach and blown-sand deposits. They concluded that the raised beaches of the area were of Ipswichian age, and that the large erratics found along the Croyde–Saunton coast had been derived from glacial sediments of the same (Wolstonian/Saalian) age as the Fremington tills and clay. They did not discount the possibility, however, that large erratics farther south around the coast of South-West England (e.g. the Giant's Rock at Porthleven) had been ice-rafted into place during an earlier (Anglian) glacial phase (cf. Mitchell, 1960). During the Devensian, the upper layers of the proposed Saalian till were redistributed by solifluction and the upper beds were disrupted by frost-action (Kidson and Wood, 1974). A similar simple sequence of Middle to Late Pleistocene events was also followed in a series of papers by Kidson (1971, 1977) and Kidson and Heyworth (1977).

Bowen *et al.* (1985) and Bowen and Sykes (1988) applied amino-acid geochronological dating methods to the raised beach deposits at nearby Saunton and Croyde, establishing an Oxygen Isotope Stage 9 age for the oldest faunal elements within them. On the basis of local stratigraphic relationships, this placed the Fremington Clay, albeit very tentatively, in Stage 12 (Anglian). Later results on shell fragments recovered from the Fremington Clay itself indicated a range of ages from Early and Middle Pleistocene to Late Devensian (Bowen, 1994b). The latter provided some support for the suggestion by Eyles and McCabe (1989, 1991) and Campbell and Bowen (1989) that the Fremington Clay could have accumulated in a glaciomarine environment during the Late Devensian.

Excavations at Brannam's Clay Pit during 1986/1987 (Croot, 1987) and in 1994 (Croot *et al.,* 1996; Gilbert, in prep.) have provided significant new data regarding the character, age and depositional environments of the succession. Croot *et al.* interpret unit A (basal gravels) as a fluvial deposit, of uncertain age, that has undergone slight deformation since deposition. They cite the relative angularity and local lithology of clasts within the unit as evidence for its origin.

Interpretation of the overlying units B, C and D, however, is much more problematic. Croot *et al.* suggest that the lower levels of unit B (mainly clay) were deposited in a quiet-water environment. Clasts, which become more frequent towards the top of the unit, are regarded as dropstones; with a single exception, their origin is relatively local. Although micromorphological examinations of the clay show strong similarities with known glaciomarine deposits, the lack of a marine fauna and the local lithology of dropstones found within the clay are taken by Croot *et al.* to indicate deposition of units B and C in a glaciolacustrine setting. Although clasts in unit B are clearly dropstones, their means of transport to the quiet-water body remains unclear. With the single exception of the striated microdolerite cobble, the remaining locally derived clasts could have been introduced on or in floes of river ice: the single glacial cobble, however, must have been dropped from a mass of glacier ice. Whether this mass of ice was a single iceberg or a more continuous sheet of floating ice remains uncertain (Croot *et al.,* 1996).

Croot *et al.* also present data from micromorphological and engineering tests to demonstrate that units A, B and C were gently deformed and partially over-consolidated following deposition. This adds weight to the likelihood that units A, B and C were overridden by glacier ice, but does not accord with the interpretation (Croot *et al.,* 1996) of the overlying material (unit D) simply as a weathered variant of unit B. Although previous workers have interpreted unit D as a basal till (e.g. Stephens, 1966a, 1966b, 1970a; Edmonds, 1972), Groot *et al.* argue that the material demonstrates a weak fabric with clast lithologies identical to those in the underlying unit. Unit E, which caps the sequence, is interpreted as a typical head deposit formed by solifluction during periglacial conditions.

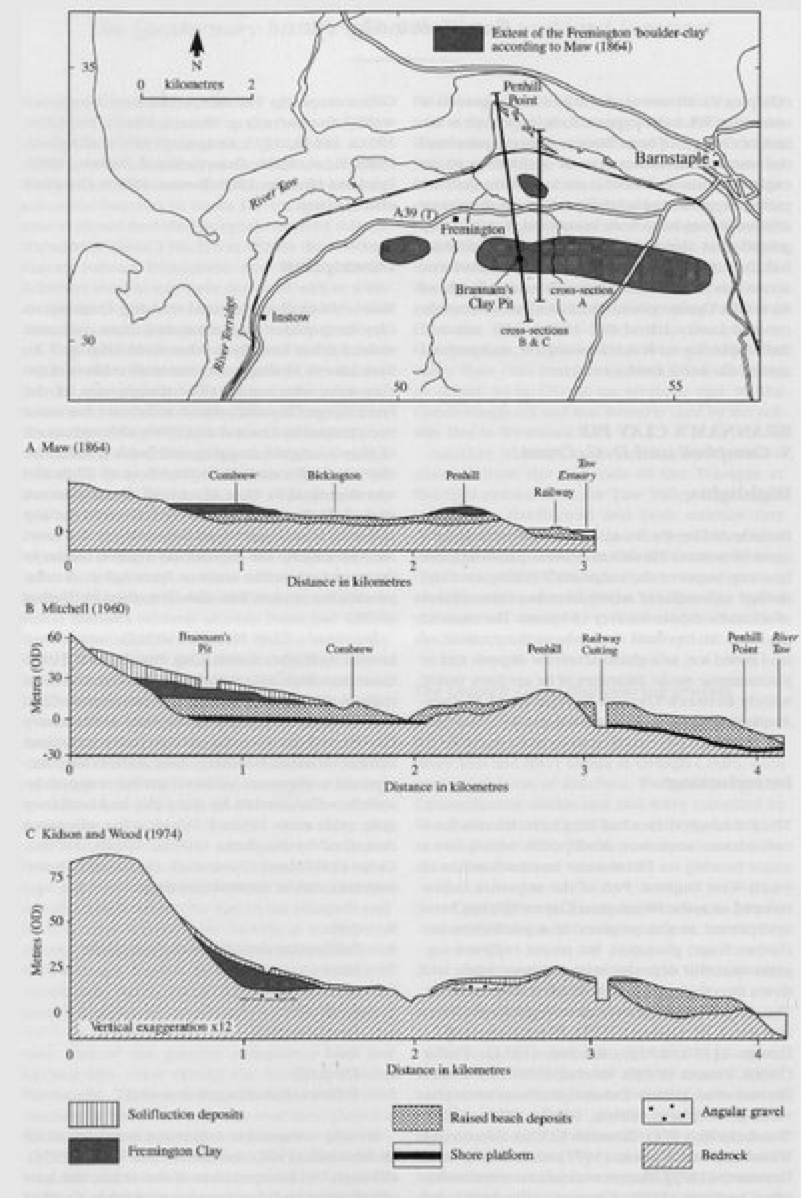
Dating of the sequence also remains highly controversial. Although recent work has shown that units B, C and D contain abundant pollen and spores, there is no material of uniquely Pleistocene age (Croot *et al.,* 1996). Indeed, some of the assemblage is directly comparable with that of the Bovey Basin clays and other Tertiary clays found in South-West England (Wilkinson and Boulter, 1980; Freshney *et al.,* 1982; Hunt, 1984; Croot *et al.,* 1996). The rest is derived from other sources to the north-west (Hunt, 1984). Equally, the nannofossil assemblage comprises a dominance of reworked Cretaceous forms and Croot *et al.* conclude that the fossil evidence alone would imply an early Tertiary age.

The application of Optically Stimulated Luminescence (OSL) dating techniques to sand samples from unit C, however, has provided potentially significant results (Croot *et al.,* 1996; Gilbert, in prep.). OSL measurements show that the sands are older than Oxygen Isotope Stage 2 (Late Devensian) and are more probably of Anglian (Stage 12) age. Large degrees of uncertainty associated with these dates, however, mean that deposition during any of the intervening evenly numbered (cold) Oxygen Isotope Stages 4, 6, 8 and 10 cannot be ruled out. On balance, however, these preliminary and unconfirmed results would point to the Fremington Clay (units B, C and D) being of Anglian (Stage 12) age.

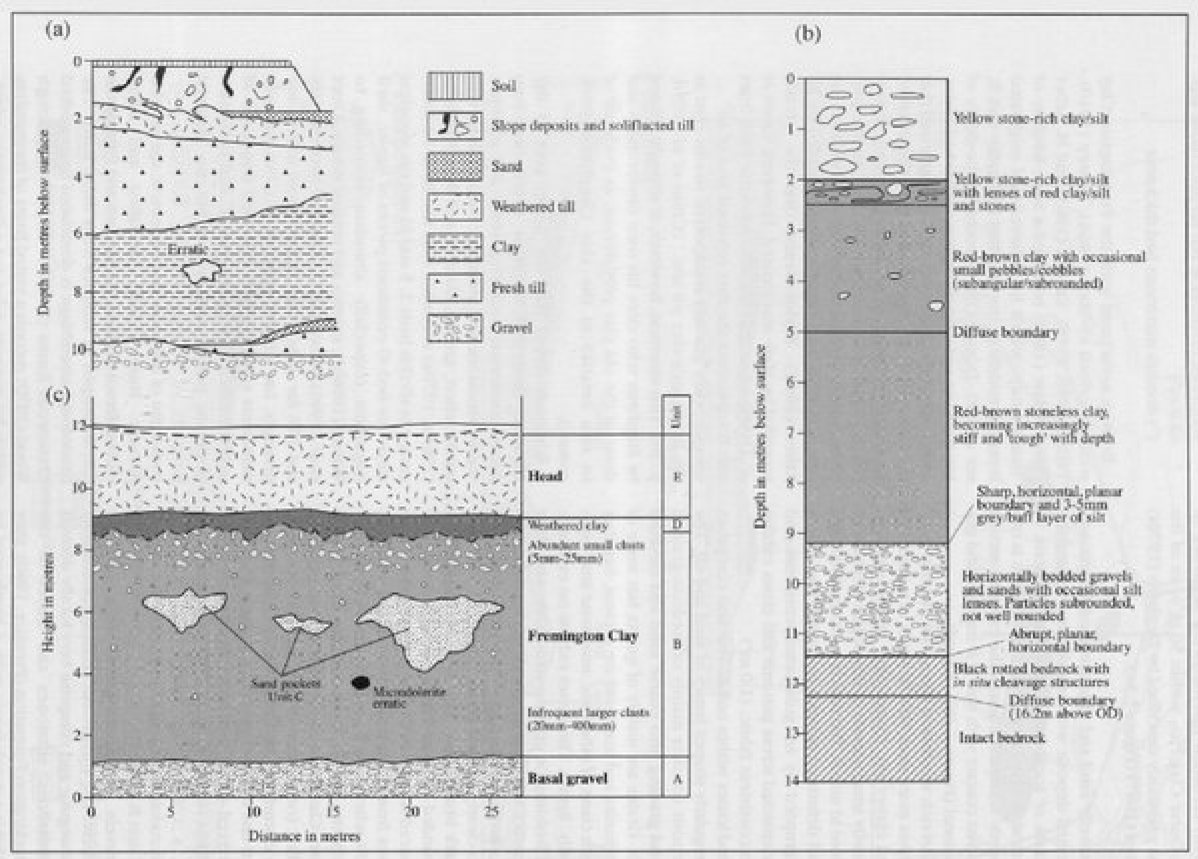
Conclusion

Brannam's Clay Pit is undoubtedly one of the most important Pleistocene sites in Britain, and the Fremington Clay has long been regarded as the ' most significant glacial deposit of the peninsula' (Kidson, 1977; p. 294). The oldest deposits at the site are gravels of probable fluvial origin. The overlying Fremington Clay, in fact a complex sequence of clay, silt, sand and stony clay, has traditionally been regarded as the product of a Wolstonian (Saalian) Irish Sea ice sheet. However, recent work suggests that the deposits are older, possibly of Anglian (Oxygen Isotope Stage 12) age, that they are overwhelmingly of local derivation, and that they may have accumulated, at least in part, in a glaciolacustrine environment. The evidence is still insufficiently precise to rule out a glaciomarine origin. The site may well prove to be one of the most southerly points of Britain to have been overrun by glacier ice.

References



(Figure 7.2) The extent of the Fremington 'boulder-clay' according to Maw (1864), and proposed stratigraphical relationships in the Fremington area. (After Maw, 1864, Mitchell, 1960 and Kidson and Wood, 1974.)



(Figure 7.3) The Quaternary sequence at Brannam's Clay Pit, Fremington. (a) Composite section of the former eastern and southern working faces, adapted from Stephens (1966a, 1966b, 1970a). (b) The succession recorded by Croot in 1987. (c) The sequence recorded by Croot et al. (1996).