Warren House Gill

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Introduction

Warren House Gill and adjacent coastal exposures show a complex Quaternary sequence and are a unique and important location in northern England for enigmatic, pre-glacial fissure sediments in the Magnesian Limestone, which may give information about the development of vegetation and climate back into the Tertiary, or at least the Pliocene–Early Pleistocene (Trechmann, 1919; Reid, 1920; West, 1968; Pennington, 1969a). It also has provided an important exposure of pre-Devensian till with Scandinavian erratics (Francis, 1970), loess (Trechmann, 1919) and a complex Devensian glacial sequence of sands, gravels, laminated clays and tills (Smith and Francis, 1967). The pre-Devensian sediments are no longer exposed as a result of tipping on the foreshore from Horden Colliery.

Description

Warren House Gill, in Durham, is situated about 2 km south-east of Easington Colliery and is an incised post-glacial valley in Magnesian Limestone cliffs that forms the back of a bay approximately 4 km long. The features of interest in the site extend further than the current site boundaries and a summary diagram of the relationships between the Quaternary deposits is shown in (Figure 4.10).

Fissure deposits

Fissures that contain a variety of sediments, including freshwater clays with plant remains, are found in the Magnesian Limestone along a 10 km length of coast (Figure 4.11) and five examples have been described between Blackhall Rocks and the entrance to Castle Eden Dene (Trechmann, 1919). Here grey and brown freshwater clays with peat, mosses, seeds, tree trunks, non-marine molluscs, ostracods, small fishes and a few mammalian bones (teeth and skull fragments of a rodent and some elephant bones) have been reported. At fissure 5 it was clear that these sediments had been glacially transported, as they were slickensided, faulted and the larger shells were broken. The seeds and other organisms were often pyritized. The stratigraphy was not clear, although it appeared to Trechmann (1919) that the brown clay, containing the majority of seeds and mammalian bones, is older than the pale blue and grey clay in which most of the freshwater shells were found. The elephant was thought to be *Elephas meridionalis* (now *Archidiskodon meridionalis* Nesti). These elephants, according to Kurten (1968), were the dominant animals in Europe during the Lower Pleistocene and into the Cromerian, when they showed a tendency to specialize into steppe and forest forms in contrast to their former habitation of savannas, bush steppes and woodlands.

The plant remains (seeds) were analysed by Reid (1919, 1920), who identified 114 species of plant, including nine mosses; 89 species of flowering plant were generically determined and 58 to the nearest living species. Sixty-four per cent of the species were either no longer growing in Britain or were completely extinct. There was a large percentage of exotic, extinct species in this Castle Eden flora, as it was called, including a considerable element of Chinese and North American species. Mammalian bones were also found at the base of fissure 4 (Figure 4.11) and occurred among rubbly, calcreted Magnesian Limestone, which had small fragments of Scandinavian gravels. The fissure is overlain by loess-like sediment, and the bones of fallow and red deer or closely allied species are older, unworn and not glacially transported any distance. The younger blue clay contained 11 British temperate species and is clearly younger. The environment was aquatic, close to the sea and probably brackish (Reid, 1920).

Scandinavian Drift or the Warren House Till

At Limekiln Gill (4 miles north-west of Hartlepool) erratics were noted above the fissure, including pink and pale-grey gneiss, porphyries and a schist (Trechmann, 1915), which resemble the types found in the Scandinavian Drift at Warren House Gill. This term, 'Scandinavian Drift', had been used first by Howse (1864) to describe a clay bed that contained flints and pieces of *Cyprina islandica* at the mouth of the Tyne and overlying Magnesian Limestone at Trow Rocks near South Shields. He surmised that the flints might have come from Denmark. This was rejected both by Boswell (in a discussion of Trechmann's (1915) paper) and by Trechmann (1919) as flints are common in the Devensian sediments of east Durham, and Scandinavian rocks were often used as ship's ballast and have been found in the Tyne and along the coast. Nevertheless, larvikite was found near the mouth of Castle Eden Dene (Boulder Report, 1910–1911), to the north of Horden and on the shore opposite Warren House Gill (Trechmann, 1915). Porphyries and nordmarkite (a red, titaniferous syenite) were also reported on this coast. All these Scandinavian erratics resemble the types found in the Scandinavian Drift clay at Warren House Gill. The Scandinavian Drift is represented by a unit preserved in a SE-trending, pre-glacial depression in the Magnesian Limestone, near the centre of which occurs a fissure of uncertain depth but approximately 40 m wide. It is a dark, compact, tenacious, sandy clay, in places slickensided and up to 5 m thick, but this rapidly thins and disappears against Magnesian Limestone at the sides of the old valley. It is devoid of erratics from northern England or Scotland, except for locally derived Magnesian Limestone, red sandstone and marl, but does contain a characteristic Scandinavian suite, including gneiss, nordmarkite, larvikite, rhomb-porphyries, other porphyries of various types, quartzites and flint and chalk. Trechmann (1915) counted 500 clasts and 80% were igneous or metamorphic (along with a grey limestone) from the Oslo district of southern Norway and 6% chalk, flint and red–green Triassic material. The Scandinavian Drift was also shelly throughout, with many broken, arctic forms, now extinct in Britain (Trechmann, 1915, 1919), and abundant foraminifera have been obtained from a new exposure (Huddart, in prep.).

Loess

The upper section of the Scandinavian Drift consists of a bed of pale brown (fawn) sediment, between 0.3 and 4 m in thickness, full of rounded concretions and almost devoid of stones and stratification, although there are occasional layers of coarse sand. The unit breaks along vertical cracks and appeared to Trechmann (1919) to be loess banked up against the north-facing slope on the southern edge of the old valley. It passes upwards into a deposit of loess redeposited by water that has horizontal bedding, sand seams and fine gravel lines.

Devensian glaciogenic sequence

Stratigraphically above the Warren House Till but below the later Devensian till are a series of gravel deposits found in depressions in the Magnesian Limestone. Usually they are under 2 m thick but at Limekiln Gill they are 4 m thick, composed of cross-stratified sand and calcreted gravel, and extend over 30 m. North of Horden Point they are over 10 m thick and both exam- pies contain unabraded shell fragments. The erratic suite is similar to the overlying till and there are no categorical Scandinavian rocks but mainly Lake District and Scottish erratics, with large percentages of gneisses, schists, Cheviot red and purple andesites, Lake District volcanics, dolerites, quartzites, Carboniferous Limestone, flint and Magnesian Limestone.

The Magnesian Limestone to the north and south of Warren House Gill is overlain by a tripartite Devensian glaciogenic sequence consisting of sands and gravels interbedded between two tills, called the Upper and Lower Boulder Clays by Smith and Francis (1967; (Figure 4.12)a). This succession is currently better exposed on the north side, where a grey-brown till, 2 m thick with red interbedded sediments, laminated and silty in places, lies above the Magnesian Limestone. This is overlain by 5 m of laminated, silty fine sand and clay units, which have had their original structure sheared into lenses by overriding ice. At Horden Point to the north of the gill an extensive glaciogenic sequence overlies 1.8 m of cavernous Magnesian Limestone and is illustrated in (Figure 4.12)b. Above this coastal stratigraphical succession at the western end of Warren House Gill, at the newly constructed Horden Sewerage Works, a complex glaciogenic sequence higher in the succession was exposed and is illustrated in (Figure 4.12)c. The Lower Boulder Clay, or Blackhall Till (Francis, 1970) attains a maximum of 15 m over this coastal plain and is the lowest stratigraphical unit formed during the Devensian ice advance and is generally a highly compacted, stiff, dark-grey or grey-brown sandy till with erratics from the Lake District or Southern Scotland. It covers most of Durham, is situated on rockhead everywhere and this rockhead is disturbed in places. Striae, till fabrics and the erratic distribution suggest ice moving from north-west to south-east across the county.

Along the eastern coastal plain the lower till is overlain predominantly by sands, called the Teterlee Sands' by Francis (1970). They are part of the Middle Sands of Smith and Francis (1967), who describe a lower, red, fine-grained sand, commonly with silt and clay beds and sporadic units of sand and gravel and an upper gravel with sands. The upper till has been called the 'Horden Till' by Francis (1970), from the type locality on the north side of Warren House Gill, and along this coast reaches a maximum thickness of about 14 m and where unweathered is a dark-brown to purplish brown, stiff clay with a similar texture to the lower till. It has a sharp base at some localities and at others the contact is gradational.

The so-called 'Prismatic Clay' generally consists of a dull brown, silty and sandy clay with scattered erratics and many pronounced columnar joints in its upper part, grading to blocky below, but in many locations has much of the characteristics of till and grades into the underlying deposit. It is weakly layered in some exposures and as Coupland and Woolacott (1926) noted it maintains a roughly constant thickness for considerable distances, even down valley sides and on to bedrock. It is widespread in eastern Durham and most common on the upper till.

Interpretation

Fissure deposits

Reid (1920) thought that the lower fissure deposits must be older than the Cromerian, by comparison with the European Middle Pleistocene to Pliocene sequences. The environment was thought to be one of a rocky or pebbly bedded river as there was the presence of species such as *Cotoneaster, Potentilla argentea* and *Oxalis corniculata,* which suggest an upland river and a rocky valley in limestone with pastures. Woodlands were indicated by some of the following: *Liquidambar* (sweet gum), *Carpinus laxiflora* (Japanese hornbeam), *Betula alba* (white birch), *Alnus viridis* and *A. glutinosa* (alder species), three species of *Crataegus* (hawthorn) that belong to a North American section of the genus and three species of Chinese and Japanese *Rubus* (blackberry). Lesne (1920, 1926) identified nine species of insects from the same material and found that three were extinct in western Europe and four were closely related to present forms. Lesne's suggestion that two of the genera 'recherchent les stations fraiches ou froides' is not inconsistent with their having a Cromerian age (Francis, 1970), as the beds formerly referred to by this name in Britain are now known to include deposits of several phases encompassing both temperate and cold conditions (West and Wilson, 1966), but Reid (1920) suggested that they confirmed the Pliocene age. Pennington (1969a) considered that, although the Castle Eden flora was of doubted age, it might be compared with the Upper Pliocene floras of Poland (Szafer, 1946), or to an earlier stage. Boulter (1971b) has suggested that there could be links between the Castle Eden flora from the lower clay and those floras of Miocene to Early Pliocene age in Derbyshire, but West (1968) preferred an early Pleistocene age. The non-marine molluscs have been reported by Kennard and Woodward (1919, p. 200), but although they indicate a fluvial habitat the faunal assemblage is undiagnostic as to age.

Reid (1920) considered the younger fissure fills to be possibly Cromerian and this is likely. There was considerable disturbance of the rock adjacent to and enclosing the fissures and in every case there was erosion across their surfaces. The fissure fills were thought not to be the result of 'collapse breccias' by Trechmann (1915) but were the result of glacial processes. He suggested that the fissures lay open before the Scandinavian ice reached the area and that they were filled with sediment carried by that ice. He considered that rock fragments in the fissures were slickensided by movement during compaction of the breccia under the weight of the overlying ice. However, it seems much more likely that the fissures were first formed during and after the solution of the sulphates following the post-Permian uplift and that most of the material from the beds now eroded away fell in at about this time. Subsequent compaction of the resultant breccias provided space for the gradual accumulation of material towards the fissure top and it is suggested that such compaction gave rise to surface depressions into which Pleistocene sediment was deposited ahead of, or under, the Scandinavian ice.

Scandinavian Drift or the Warren House Till

Trechmann (1915) correlated the fauna in the Scandinavian Drift with the fauna from the Bridlington Crag in Holderness. The Scandinavian Drift, or Warren House Till, indicates a major cold period sufficiently long and intense for a large ice cap to have formed over Scandinavia and extending as far as the East Durham coast. Trechmann preferred an origin by Scandinavian land-based ice approaching the Durham coast rather than ice-rafted glaciomarine sedimentation, especially as Swedish quartz-porphyries and rapakivi-granite have been found on the southern Yorkshire coast but not on the Durham coast. Such an ordered distribution could not be explained by icebergs floating randomly across the North Sea and hence he concluded that this must have been a terrestrial ice sheet. However, Beaumont (1968) argued that this till was deposited from a floating ice shelf that did not come into contact with any bedrock until it grounded close to the Durham coast. During this grounding stage it incorporated the arctic marine fauna. This helped explain how the Scandinavian ice could reach the British coast before local ice from western Britain could arrive. Hence there is no need to postulate that the Scandinavian ice sheet expanded more rapidly, for once the ice sheet became buoyant its thickness would be greatly reduced and its speed of advance as an ice shelf would be increased by a factor of five to ten times compared to its terrestrially based speed. At the height of the glaciation the sea level in the North Sea would fall and therefore the floating ice shelf would have become grounded at progressively greater distances from the Durham coast. Therefore the invasion of the Durham coast took place during the very early stages of the glacial phase and it was the first ice to reach the coastal area. The Warren House Till has been correlated with the Basement Till of Holderness and has been thought to be Wolstonian in age (Smith, D.B. *et al.,* 1973; Lunn, 1995; Hughes *et al.,* 1998). However, West (1963) and Smith and Francis (1967) attributed it to the Anglian.

Loess

The overlying loess is gradational with the Warren House Till and there are contortions in both, and therefore ice must have overidden this sediment, although the main mass of loess is banked up against the valley after the Scandinavian ice sheet had begun to retreat. This loess probably indicates a cold periglacial zone with outblowing winds from the end of the Wolstonian glacial (Shotton, 1981) and not as Trechmann (1919) thought from an interglacial. Smith and Francis (1967) placed it in the Hoxnian interglacial. However, this loess and loess in soils developed over the Magnesian Limestone outcrops could have been emplaced in an extraglacial, early Late Devensian environment according to Catt *et al.* (1974). Thus again there is dispute as to the time period of deposition for this loess.

Devensian glaciogenic sequence

There seems to be two possible origins for the gravels in depressions in the Magnesian Limestone: they might be associated with subglacial (Trechmann, 1915), or pro-glacial (Smith, 1981) glaciofluvial transport, but related to ice advance probably during the Devensian.

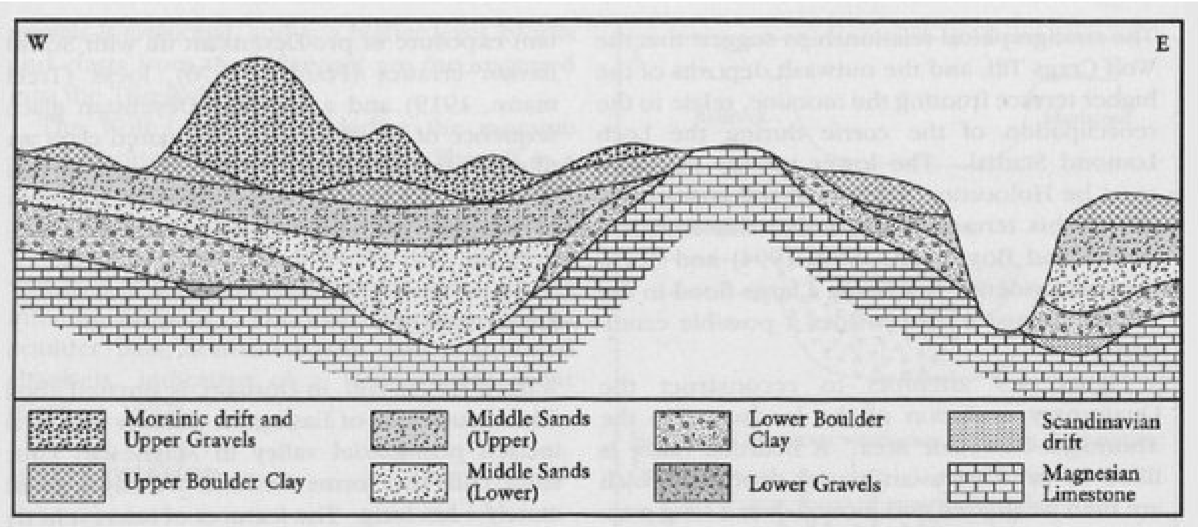
Evidence for a period of deglaciation between the upper and lower till sheets is meagre and is confined to two possible weathering horizons developed on the surface of the lower till. In the inland valleys the ice melt between the upper and lower tills led to the deposition of thick glacio-aqueous sediments called the 'Durham Complex' by Francis (1970). During deglaciation, water in both subglacial and supraglacial environments led to a variety of sediments and landforms. The laminated silty clays shown in (Figure 4.12)c indicate pro-glacial glaciolacustrine sedimentation, but whether it was in this phase, or associated with a later readvance is debatable. The lower sands have been interpreted as outwash from the ice that deposited the underlying till and the upper gravels and sands from ice that deposited the upper till. The extent of the Horden Till (Upper Till) shown in (Figure 4.14) implies that during deglaciation the margin of the ice lay along the present coastal zone and it is probable that considerable quantities of meltwater were liberated and that laminated clays were deposited in lakes (possibly the laminated clays at Horden Sewage Works), and that a number of glacial drainage channels survive from this period. The till-fabric pattern suggests movement of ice down the present-day coast and impinging on to the Tees lowlands (Figure 4.13). This unit has fewer — but more far-travelled erratics — than the lower till. There are disturbances reported in the underlying sediments below the Horden Till, as in (Figure 4.12)c and at Sheraton, where in a road cutting a large thrust fault was visible in laminated clays, which did not pass up into the overlying till. These situations indicate disturbance of the laminated clays caused by the ice advancing. There are glacial landforms associated with this upper till ice, such as the NNW-trending ridges forming moraines with an east-facing ice-contact slope between Easington and Elwick and the pro-glacial lake Edder Acres, which overflowed through channels, as at Kelloe (Figure 4.14) and (Figure 4.15). Laminated clays were deposited in this lake, as at Shotton brickpit, as advancing ice blocked existing drainage. Evans (1999) suggested that a lobe of Tweed–Cheviot ice, probably on a deforming bed, remained active along the north-east coast after ice from the west (Tyne Gap and Stainmore) had wasted away, and caused pro-glacial lacustrine sedimentation.

It seems probable that the Prismatic Clays have been derived *in situ* by deep frost action or effects of drying out and weathering. As Coupland and Woolacott (1926) suggest, it was formed by 'the processes of denudation ... in part rainwash, in part wind-formed and in part weathering *in situ.'*

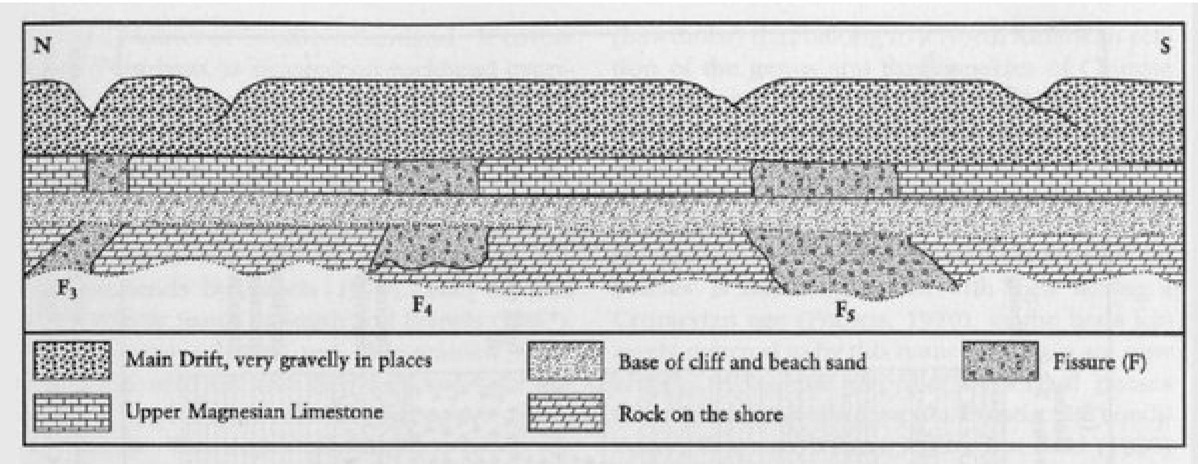
Conclusions

The deposits reported by various authors from Warren House Gill and the surrounding Durham coast have revealed an extremely important Quaternary succession. Some of the fissure deposits go back at least to the Early Pleistocene, and the younger fissure deposits are probably Cromerian in age. Both the older and younger fissure deposits appear to be much older than most other Quaternary deposits in northern England, apart from the Derbyshire pocket deposits. The Devensian sequence at Warren House Gill and along the adjacent coast is typical of much of County Durham and illustrates the variety of deposits and environments laid down during the advance, retreat and readvance of a complex ice sheet.

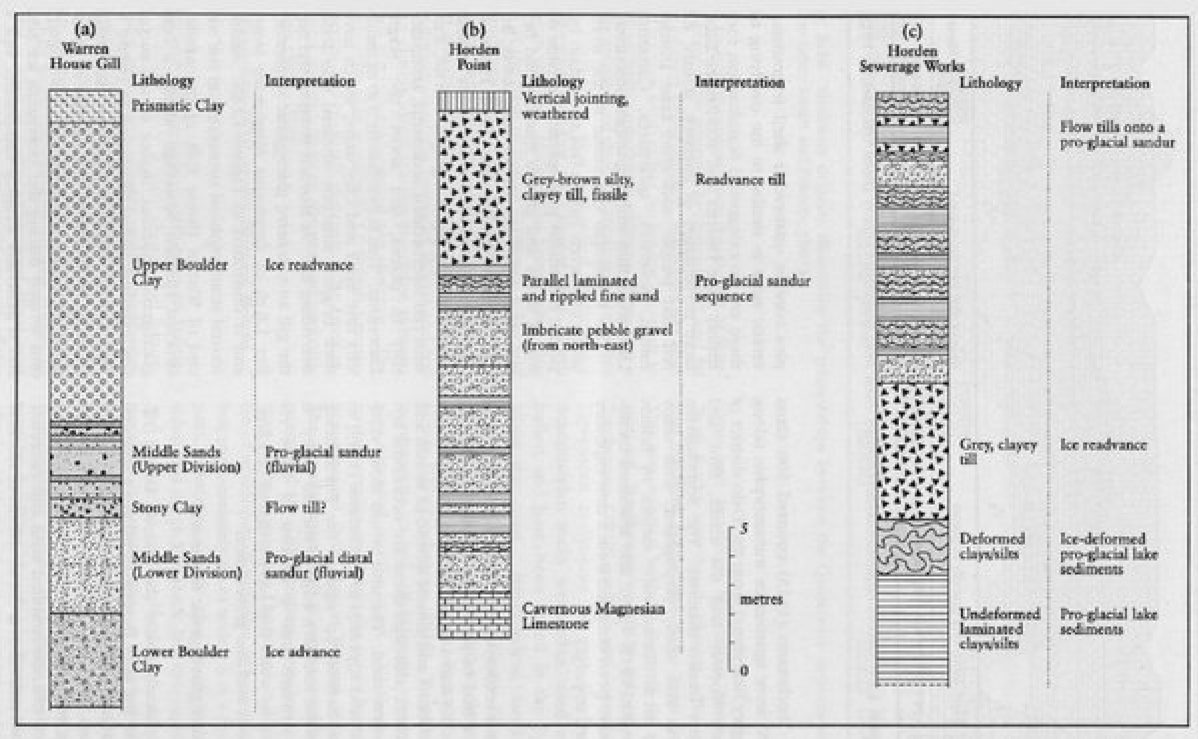
References



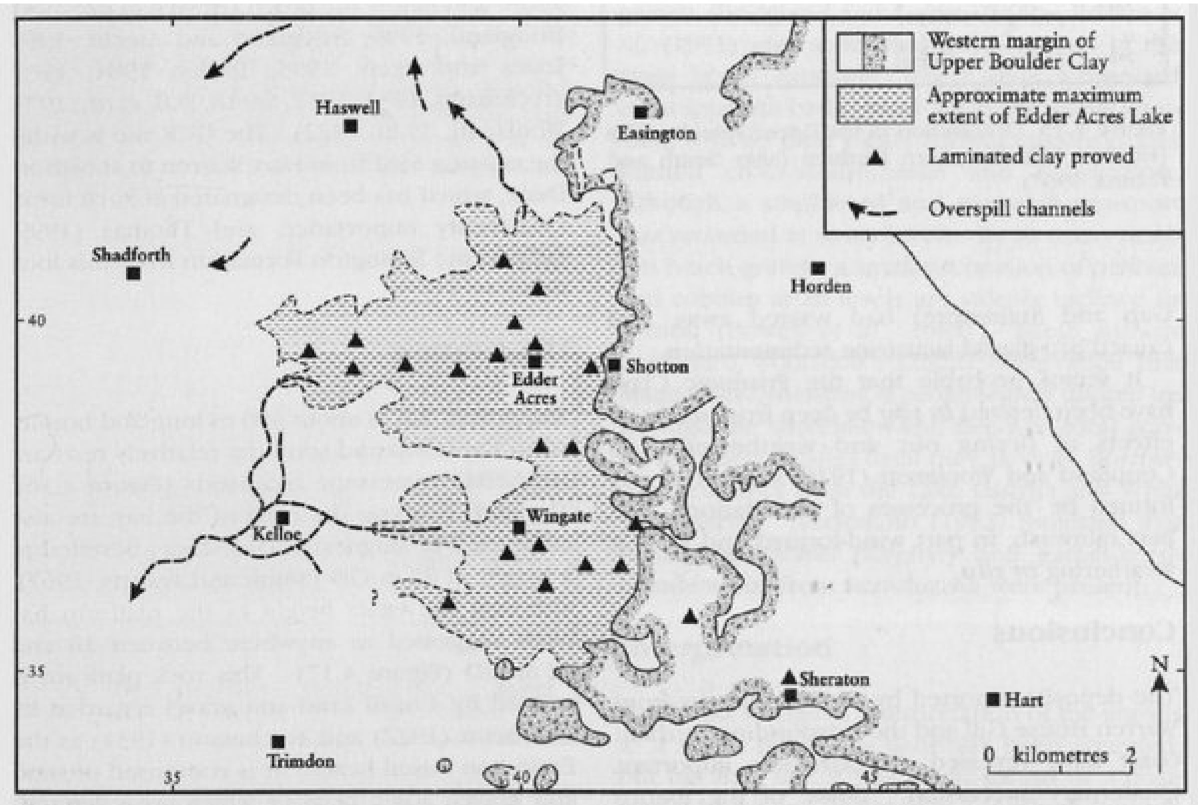
(Figure 4.10) Summary diagram illustrating the relationships between the Quaternary deposits in eastern Durham (after Smith and Francis, 1967).



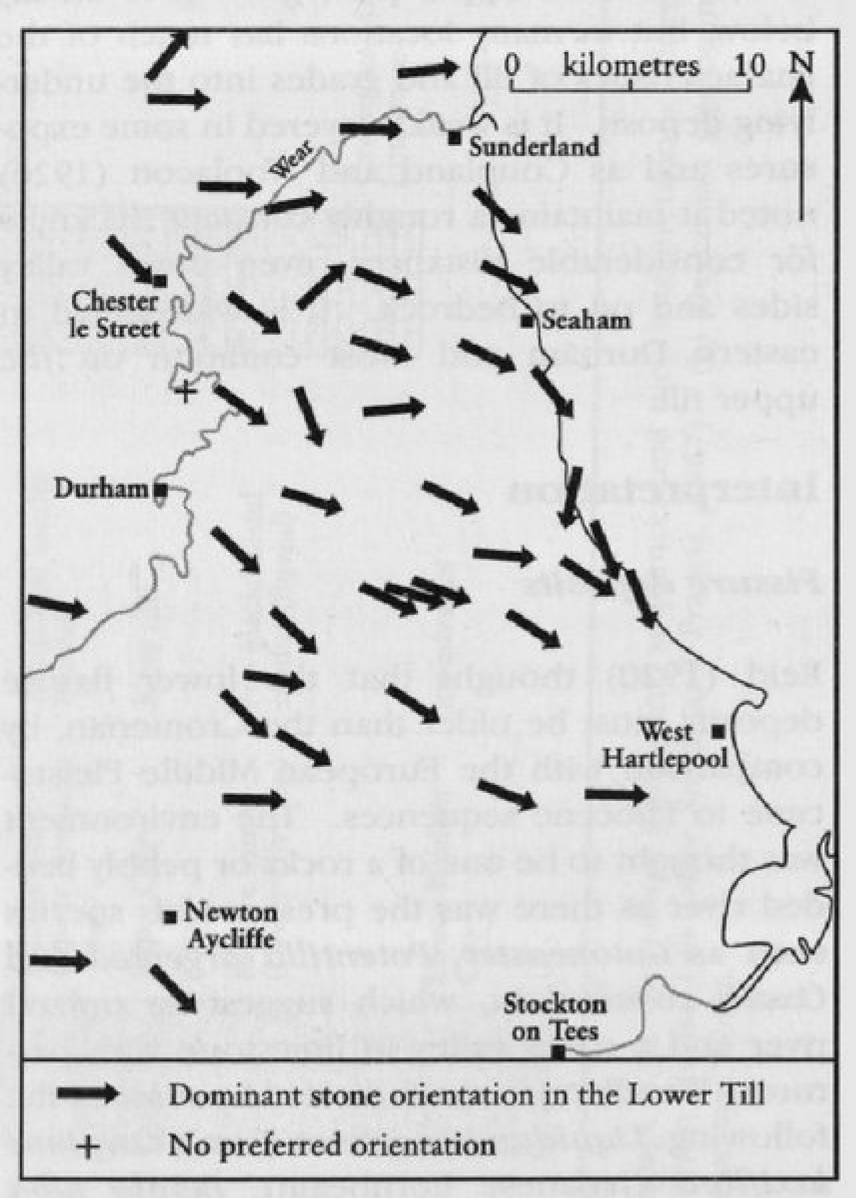
(Figure 4.11) Fissure deposits on the Durham coast near Blackhall Colliery (from Trechmann, 1919).



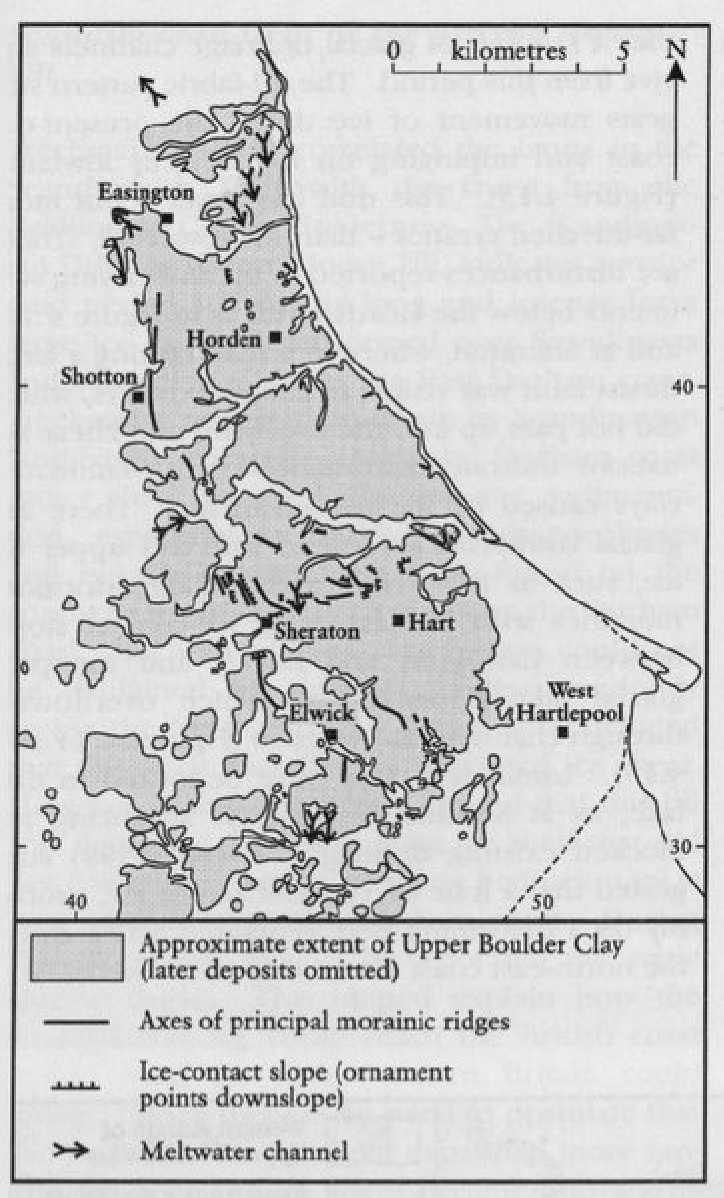
(Figure 4.12) Devensian glaciogenic sequences and their interpretation: Warren House Gill and Horden. (a) Tripartite Devensian glaciogenic sequences, Warren House Gill (after Smith and Francis, 1967). (b) Devensian glaciogenic sequence, Horden Point. (c) Devensian glaciogenic sequence, Horden Sewerage Works.



(Figure 4.14) Lake Edder Acres, eastern Durham (after Smith and Francis, 1967).



(Figure 4.13) Stone orientation directions from the Lower Till, eastern Durham (after Beaumont, 1971).



(Figure 4.15) Distribution of the Upper Boulder Clay (Horden Till) in eastern Durham (after Smith and Francis, 1967).