St Bees

[NX 965 113]

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Introduction

This site in Cumbria is of considerable importance for interpreting Late Devensian glacial events and Late-glacial environmental conditions in north-west England. The major interest is the St Bees moraine [NX 965 113] (Figure 5.56), a series of low ridges and hummocks situated at the south-west end of the fault-guided, Whitehaven–St Bees glacial valley. The moraine extends from Gutterfoot in the north-west to Sea Mill in the south-east (Figure 5.57). Sections in the moraine have been described by Eastwood *et al.* (1931), Huddart (1970, 1972, 1991, 1994), Huddart and Tooley, (1972), Huddart *et al.* (1977), Tooley (1977), Eyles and McCabe (1989), Walden *et al.,* (1994) and Merritt and Auton (1997a, b). The moraine was considered by Huddart (1970, 1991, 1994) to mark the terminal position of the Late Devensian Scottish Readvance episode, by Evans and Arthurton (1973) and Thomas (1985b) as a response to local ice-marginal oscillation during the retreat of the main Devensian glaciation, and by Eyles and McCabe (1989) as a glaciomarine morainic bank.

On its surface the moraine has a series of organic filled kettleholes that have been interpreted using pollen (Walker, 1956, 1966b) and coleopteran (Pearson, 1962; Coope and Joach im, 1980; Coope, 1994) analyses. These give important quantitative estimates of Late-glacial palaeotemperatures (Atkinson *et al.,* 1987; Coope, 1994; Coope *et al*,1998) and show evidence for environmental conditions during the Windermere Interstadial and the Loch Lomond Stadial. There also are Flandrian peats exposed on the foreshore.

Description

Glacial succession

The stratigraphy is complicated and in Eastwood *et al.* (1931) the greater part of the succession was interpreted as 'Lower Boulder Clay' and 'Middle Sands and Gravels', with an 'Upper Boulder Clay' found only as a small outlier, north of Sea Mill, and to the south of Marsh House. The outlier was described as 'a section showing laminated beds with two layers of peat which had been contorted by a thrust from seaward and were overlain by undoubted "Upper Boulder Clay"' (Eastwood *et al.,* 1931). As the peat contained a temperate flora it was claimed that it represented an interglacial episode.

Unfortunately this critical section was eroded by the sea in 1924, but in the discussion of Walker's (1956) paper, Hollingworth stated that 'although Chandler's recognition of the temperate character of the flora of the peat-bearing sands between two boulder clays in Eastwood *et al.* (1931) appeared to establish the interglacial age of the deposits ... more than a little doubt was felt by some of Smith's colleagues as to whether the "Upper Boulder Clay" was *in situ* and not a reworked deposit.' These doubts seemed justified as Walker (1956, 1966b) and Pearson (1962) showed that the organic deposit was of Devensian Late-glacial, rather than interglacial, age.

The stratigraphy is illustrated in (Figure 5.58) and is derived from Huddart (1970, 1994) and Merritt and Auton (1997a, b). The lowest stratigraphical unit, the Lowca Till is between 4 and 10 m thick and is a stiff, pebbly and sandy diamicton with occasional sand lenses. It has a well-developed fabric showing resultant orientations between 257° and 310°. It contains angular to subrounded clasts of the local, Triassic, red sandstone up to 1 m diameter, with some granite, Borrowdale Volcanic lithologies, slate, Ennerdale granophyre, Coal Measure sandstones and mudstones, limestone and ironstone. Its lower boundary is on red sandstone north of the beach and its upper boundary is erosional, overlain by gravel.

The St Bees Silts and Clays are exposed in the core of a large fold and are at least 5 m thick. They consist of repetitions of grey-blue silty clays, brown-red clay and a parallel laminated, yellowish-brown silt or fine sand division. The unit has an overall horizontal bedding and is laminated but there is much disturbance of the original structure, with small faults, brecciated zones and contorted stratification, as well as the large-scale folding. A record from a borehole nearby suggests that this unit lies on the Lowca Till. The upper boundary is gradational with the overlying St Bees Sands and Gravels.

The St Bees Sands and Gravels consist of alternations of parallel laminated fine and medium sand and small-scale, cross-stratified sands, with thin intrastratal contorted stratification units. Towards the top the sands pass upwards into thin, pebble gravel units, alternating with parallel laminated, fine and medium sands and horizontally stratified, coarse sand. These, in turn, pass upwards into gravel. The thickest development of the gravel is at the south end of the main cliff section, where cobble and boulder gravel form the whole succession. These gravels show imbrication in places that suggests a west–east palaeoflow.

The St Bees Till is between 1.5 and 10.0 m thick and is present along most of the main cliff. It is a reddish brown, matrix-supported, sandy clay, relatively pebble-free (Huddart, 1971a). It has included sand lenses and clasts and tends to break up along horizontal, sandy fissility planes. Microfabric analyses show a resultant orientation from 275°. The till grades upwards into a sandy clay, between 2 and 8 m thick and gradually becomes pebble-free. The unit is disturbed and displays load casts, contorted stratification, flame and shear structures and faults.

The succession was revised by Merritt and Auton (1997a, b), who identified three units. The Gutterfoot Sand member, equivalent to the sandy clay above the St Bees Till; The How Man Till member, equivalent to the St Bees Till, and the Peckmill Sand Member equivalent to the St Bees Sands and Silts.

The sequence displays considerable large-and small-scale glaciotectonic deformation, especially in the northern part of the section. Deformation structures include conjugate extensional faults, vertical faults, thrust faults and folds (Eaton, 1997). Many structures are thrust-related and show slickensides on bedding surfaces, indicating that they were formed by a flexural slip process resulting from buckling due to compression. Directional data from bedding planes indicates a shortening azimuth of 320–140°, with thrusts showing a general dip to the north-west and a transport direction to the south-east. Seismic refraction data acquired by Nirex (1997b) have allowed a balanced cross-section (Figure 5.59) for the more deformed northern part of the section to be constructed (Eaton, 1997). The shortening is 14%, or approximately 80 m of cumulative thrust transport. It includes two areas of backthrusts to the south and intimately associated with the thrusting process is extensional faulting, resulting in numerous minor, conjugate normal faults.

Late-glacial succession

In kettleholes on the surface of the moraine, sequences display more than 4 m of organic clay, sand, peat and detritus mud. The peat was described as the 'Seacote Peat Member' by Merritt and Auton (1997a, b). The pollen stratigraphy, described by Walker (1956) was later attributed to the classic Late-glacial pollen zones by Pearson (1962) during his investigations of the Late-glacial Coleoptera and the recalculated pollen diagram (Walker, 1966b) is shown in (Figure 5.60). A number of local pollen assemblage zones were recognized and their characteristics are as follows.

C4 Dry-land herb pollen dominant. *Salix* abundant, then declines. *Betula* overwhelmingly dominant over *Pinus.* Large but declining frequencies of *Betula nana.* Gramineae more abundant than Cyperaceae and *Artemisia,* Caryophyllaceae frequent throughout.

C5 Pollen of dry-land herbs remains dominant over trees, the frequency of *Betula* increases to 20% of the pollen sum and *Salix* is abundant during the latter half. *Artemisia* and Caryophyllaceae values are low. *Empetrum* present.

C6 *Salix* pollen more abundant and *Juniperus* first recorded. *Helianthemum* consistently present.

C7 Pollen of herbaceous taxa rise in frequency to dominance over trees. *Pinus* frequencies low but continuous. *Helianthemum,* Compositae, Caryophyllaceae and *Empetrum* more frequent than hitherto.

C8 Tree and shrub pollen rare. Frequencies of Gramineae, Caryophyllaceae, Compositae and *Empetrum* are all higher than in C7 and *Artemisia* and *Rumex* are frequent.

In order to investigate the apparent discrepancy between the climatic inferences drawn from the Coleoptera and the classic interpretation based on pollen analysis, the insect fauna was re-examined by Coope and Joachim (1980). The long and complicated coleopteran sequence can be condensed by grouping the species into seven biogeographical categories and the occurrence of species in each of these categories in the stratigraphical succession is shown in (Figure 5.61), where the thermally sensitive species occur in an orderly sequence, with the most thermophilous at the base and the cold-adapted species towards the top. Many ^{14}C dates have been obtained from this sequence (Godwin and Willis, 1959; Walker 1966b; Coope and Joachim, 1980), but some are thought to be erroneous and only 4. out of 11 were accepted by the authors.

The Pow Beck Peat Member (Merritt and Auton, 1997a, b) comprises Flandrian peats exposed occasionally on the foreshore at Seamill, as described by Pickering (1878) and Kendall (1881), and to the south-west of the Seacote Hotel, as described by Eastwood *et al.* (1931). A piston-sample of peat at 2.1–2.2 m in Borehole QBH19 at St Bees gave a ^{14}C date of 7360 years BP, confirming a mid-Flandrian age (Nirex, 1997b).

Interpretation

Glacial succession

The Lowca Till was interpreted by Huddart (1970) as a basal, lodgement till of the main Late Devensian glaciation. This ice was responsible for striae on St Bees Head and the drumlin belt from Edenside to just south of St Bees. During the decay of this ice sheet, meltwater erosion produced the subglacial chutes and channels around St Bees Head and the Whitehaven–St Bees valley. The St Bees Silts and Clays were considered by Huddart (1970) to be glacio-lacustrine deposition in a pro-glacial lake as regional drainage was blocked off by the r Scottish Re-advance of Irish Sea ice at the western end of this valley. Merritt and Auton (1997a, b) considered these deposits to be the bottomsets/toesets of a delta formed by meltwater flowing from the valley during deglaciation of the main Late Devensian ice sheet and Eyles and McCabe (1989) considered them part of a glaciomarine sequence. However, there is no fauna in these deposits to substantiate a glaciomarine origin.

The St Bees Sands and Gravels were considered by Huddart (1970) to represent a gradual ice advance towards the St Bees area from the Irish Sea basin. The lower part of this sequence indicates a low energy, distal sandur but the flow regime and grain size changed vertically to produce the proximal, pro-glacial outwash and pebble, cobble and boulder gravel units. Merritt and Auton (1997a, b) suggest that this member was probably laid down by meltwater at the margin of the Irish Sea ice-stream of the main Late Devensian ice sheet during deglaciation and the Gosforth Oscillation and Scottish Readvance events. Both the St Bees Till and the sandy clay (Gutterfoot Sands of Merritt and Auton, 1997a, b) are considered by Huddart (1970) to be separate subglacial facies deposited as the ice readvanced from the Irish Sea basin. As the ice advanced over the previously deposited, pro-glacial sediments there was erosion, reworking, folding, normal faulting, thrusting and brecciaton of these sediments, both pro-glacially, sub-glacially and englacially. The St Bees Till and the Gutterfoot Sand were considered to be deposition from the melt-out of the sediment-rich, basal ice layers as the glacier stagnated. This stagnation resulted in the hummocky topography, with many kettleholes the result of individual ice blocks melting out. The stratigraphy therefore was representative of a change from distal pro-glacial to subglacial or englacial sedimentation.

The depositional environment of the Gutterfoot Sand was thought to be unclear by Merritt and Auton (1997a, b) as the primary sedimentary structures had been destroyed by glaciotectonism. However, they did consider that deposition possibly occurred shortly before the Scottish Readvance in pro-glacial lakes. It is possible that the terminal moraine marks one of the limits of McCabe *et al.'s* (1998) Heinrich I events in the northern Irish Sea basin and/or represents a surge position of the ice sheet. Merritt and Auton (1997a, b) considered that it was possible that the bed-parallel shearing in the deposits resulted from subglacial deformation, but if this was so they considered that the overriding must have occurred before the Scottish Readvance because they considered that the whole sequence was pro-glacially tectonized during the Scottish Readvance. They considered the St Bees Till to be a deformation till formed mainly of sediment derived from the Irish Sea basin and redeposited beneath the Irish Sea ice-stream during the Gosforth Oscillation. Hudd-art (1997) nevertheless considers that this pro-glacial deformation phase can be followed by englacial and subglacial deformation and that all the sediment sequence above the Lowca Till can result from the same Scottish Readvance phase. Eyles and McCabe (1989), however, thought that the well-dispersed clasts in the St Bees Till were ice-rafted debris (dropstones) and the unit was a glaciomarine mud drape.

Walden *et al.* (1994), in discussing the lithologies of the clasts in the St Bees Till, confirm the presence of large proportions of local rock types, as first suggested by Huddart (1970). Whatever the depositional process responsible for these sediments it was able to actively erode local bedrock. Eyles and McCabe (1989) suggest that the diamictons and gravels were deposited as subaqueous debris flows directed along a bedrock channel from an ice margin situated inland. As there is a relatively narrow outcrop of St Bees Sandstone along the current coast it would seem that such an ice margin could not have been situated very far inland if such erosion was to occur. This argument is true of the upper diamicton because it also contains significant percentages of local sandstone. Walden *et al.* (1994) suggest too that the St Bees Sandstone clasts show greatest concentrations towards the base of the lower diamicton and that this could indicate some compositional vertical stratification, and such patterns can be best explained by the glacioterrestrial model. In its simplest form, vertical stratification of a diamicton's lithological composition could be expected in response to variations in the sequence of up-ice outcrop geology, and it is less easy to argue how compositional stratification could be achieved in subaqueous debris flows.

The How Mill Till was considered by Merritt and Auton (1997a, b) to be laid down during the Scottish Readvance by the Irish Sea ice-stream, but it was considered to be part of the St Bees Till by Huddart. The Peckmill Sands were considered by Merritt and Auton (1997a, b) to have accumulated as debris flows and sheetwash derived from the Irish Sea ice-stream during its retreat following the Scottish Readvance, and it has been identified along the coast between St Bees and Ravenglass.

Late-glacial succession

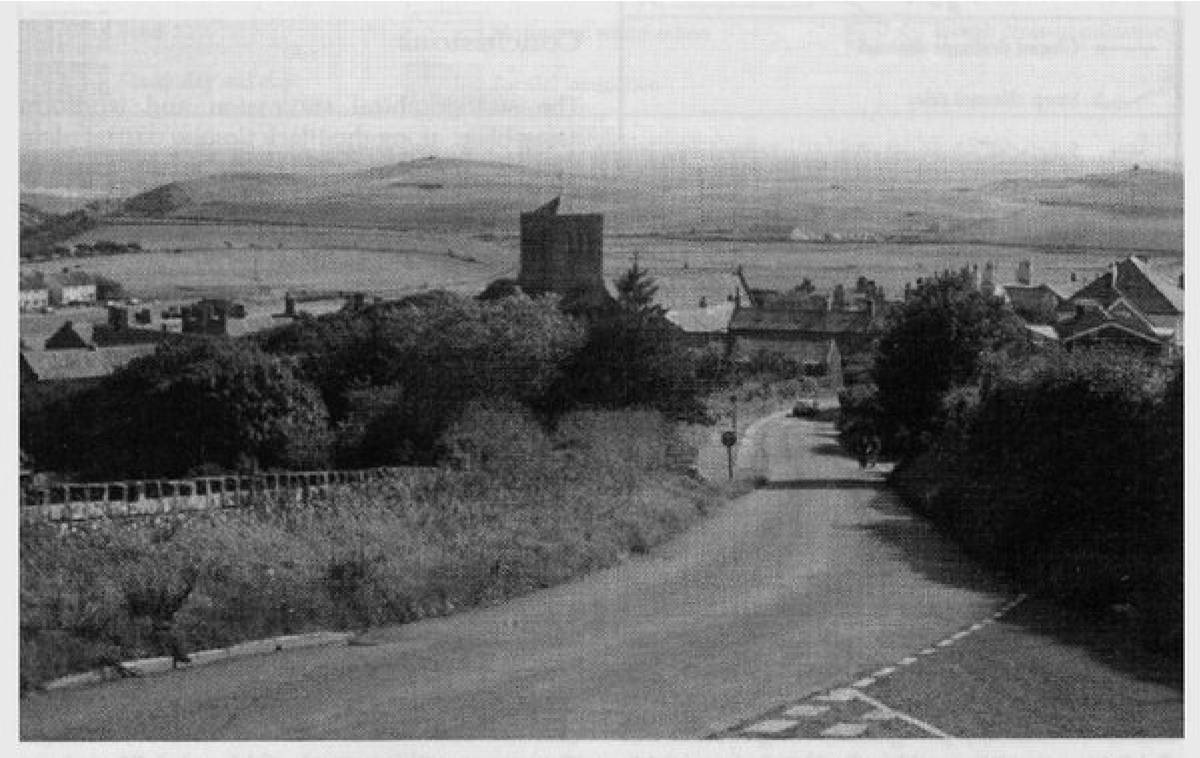
The Late-glacial succession has allowed Coope (1994) to quantify the thermal climate in terms of the mean July temperature using the Mutual Climatic Range method (Atkinson *et al.,* 1987), but because the early cold phase is missing from the St Bees sequence, data from Glanllynau in north-west Wales have been spliced on to the diagram to give a more complete Late-glacial climatic picture (Figure 5.61). The method uses the measured correspondence between the present-day geographical ranges of particular beetle species and the distribution of modern climatic variables as measured by meteorological stations. The range of each species can then be plotted on climate space, with each species being allocated its own particular climatic envelope. Palaeoclimatic conditions can then be inferred from the coordinates of the area of overlap of the climatic envelopes of the species comprising the fossil assemblage. The coleopteran faunal assemblages from the lowest horizon (II, (Figure 5.61)) show a temperate assemblage, with species having present-day distributions that are largely in central and southern Europe, indicating warm summers and an open, largely treeless landscape (Coope, 1994). Upwards, into unit III, there is a total disappearance of the southern species, which are replaced by northern species, indicating a marked climatic deterioration, with average July temperatures around 13°. At the top (unit IV) there are indications of still further deterioration, with an increase in numbers of northern species and a marked arctic/alpine element, when the average July temperatures were *c.* 10°. All the botanical, sedimentological and oceanic evidence points to a climate of glacial severity and in a short time, as the great thickness of these sediments at St Bees testifies to the importance of active periglacial slope processes that filled the sedimentary basin. It was noted initially at St Bees that the rise of the tree birch pollen curve is correlated with the first major fall in temperature after the thermal maximum of the Late-glacial Interstadial (Coope and Joachim, 1980), but subsequently this has been found to be a widespread phenomenon in Britain.

Conclusions

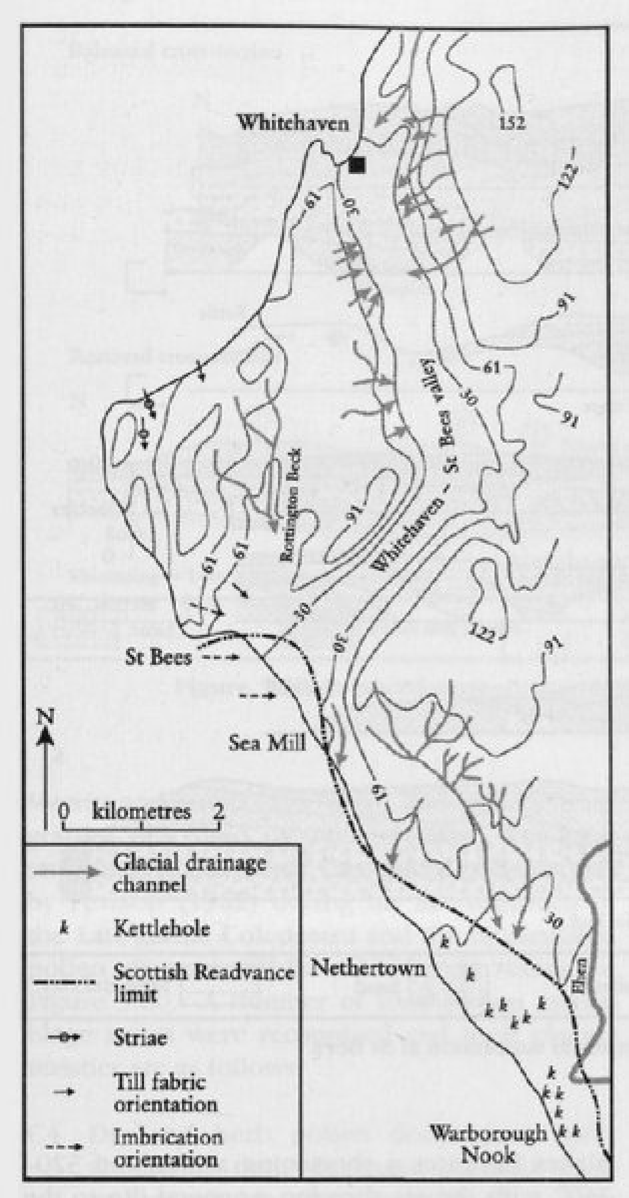
St Bees is an important Devensian site in northern England as it has prompted much controversy regarding its stratigraphical interpretation and the consequent interpretation of Late Devensian glacial retreat conditions. These interpretations range from glaciomarine (Eyles and McCabe, 1989), minor terrestrial readvance during the main Devensian retreat stage (Evans and Arthurton, 1973; Thomas 1985b), major ter restrial readvance during the Scottish Readvance (Huddart, 1970, 1991, 1994, 1997; Huddart and Clark, 1994) to a more complex formation during the deglaciation from the main Late Devensian glacial, through both the Gosforth Oscillation and Scottish Readvances (Merritt and Auton, 1997a, b). There is still no overall agreement but there seems little doubt that the sequences are caused by terrestrial glacial readvances. This view is confirmed by Eaton (1997) in his discussion of the mechanics of deformation of the moraine.

The Late-glacial succession shows the classic vegetational patterns associated with this period of rapid climatic change and is an important site from the point of view of the vegetational succession, dating and the palaeoclimatic extrapolations that have been made from the coleopteran faunas.

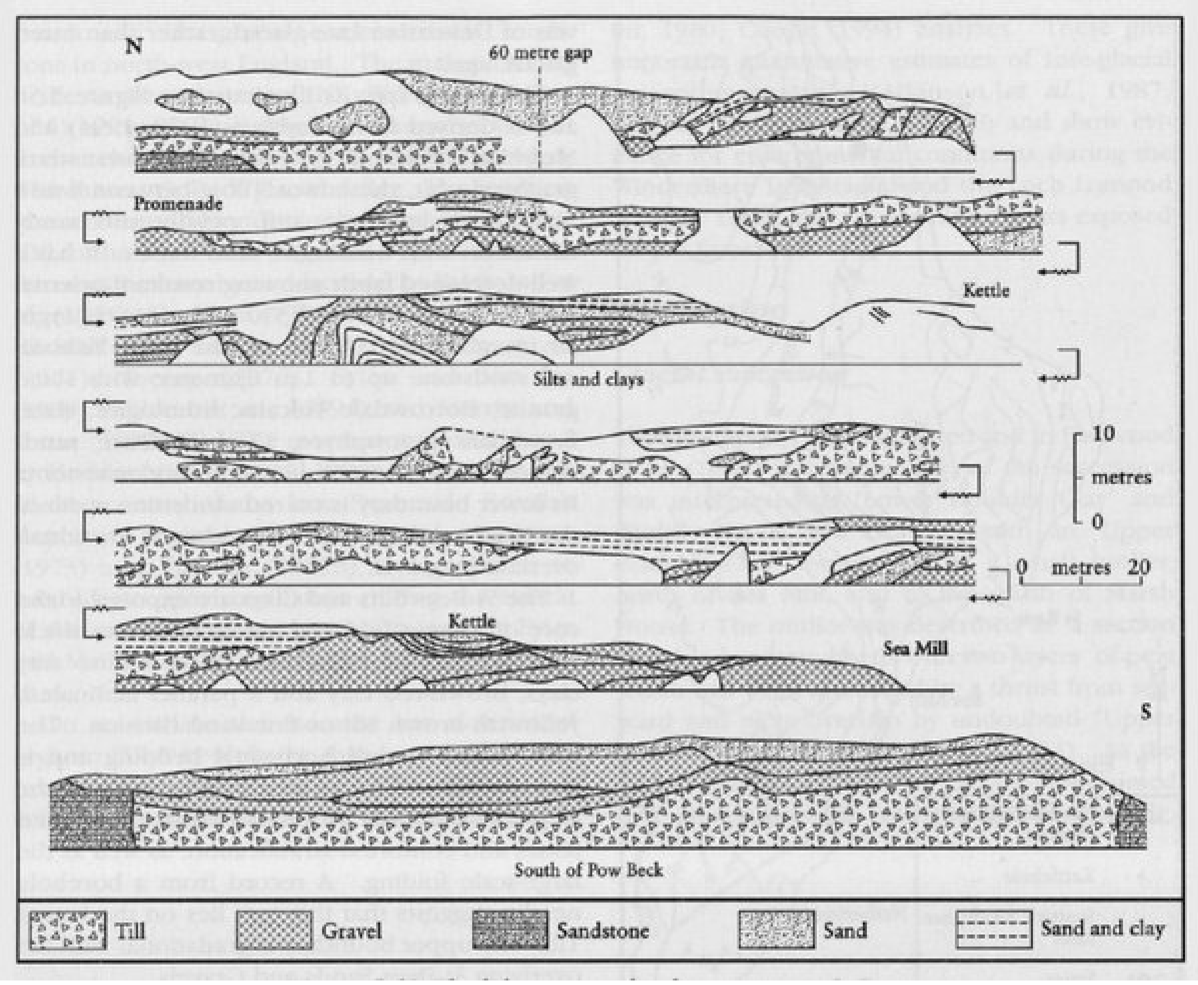
References



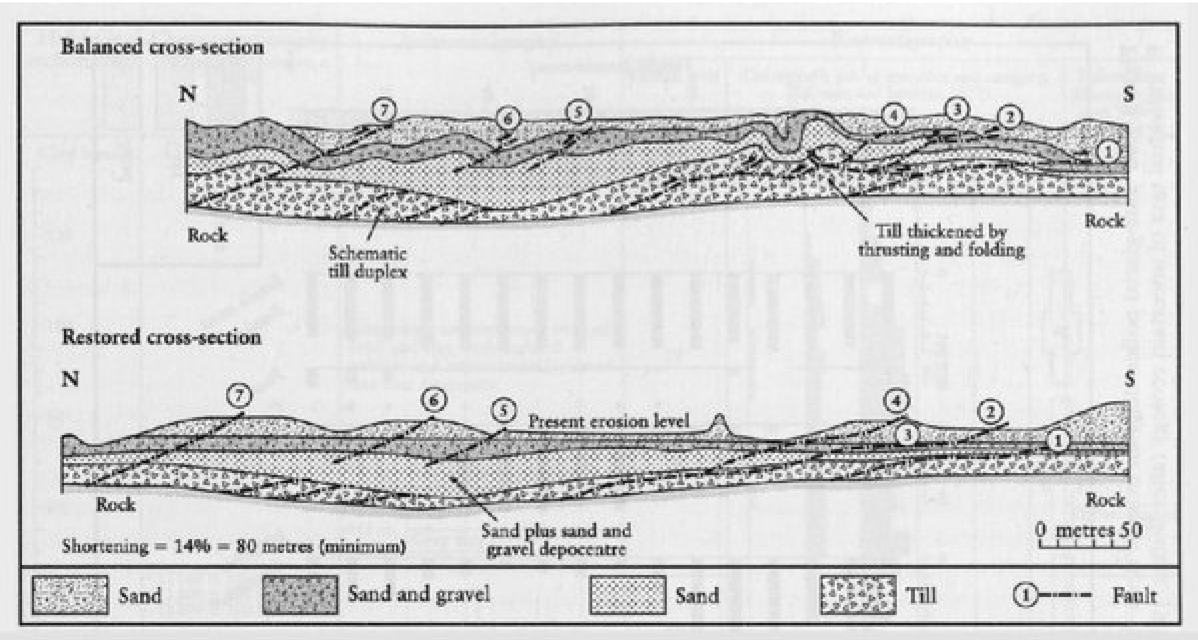
(Figure 5.56) The St Bees moraine blocking the western end of the St Bees-Whitehaven valley. View looking south-west. (Photo: D. Huddart.)



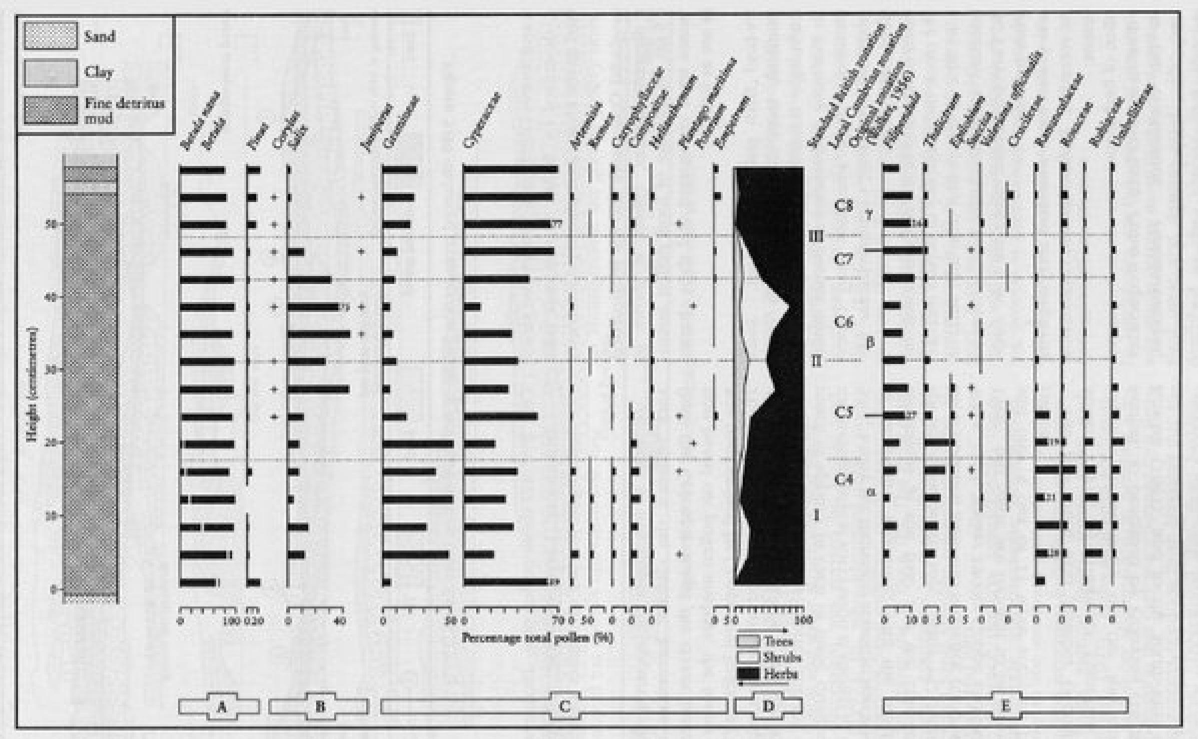
(Figure 5.57) Location and morphology of the St Bees area (after Huddart 1994).



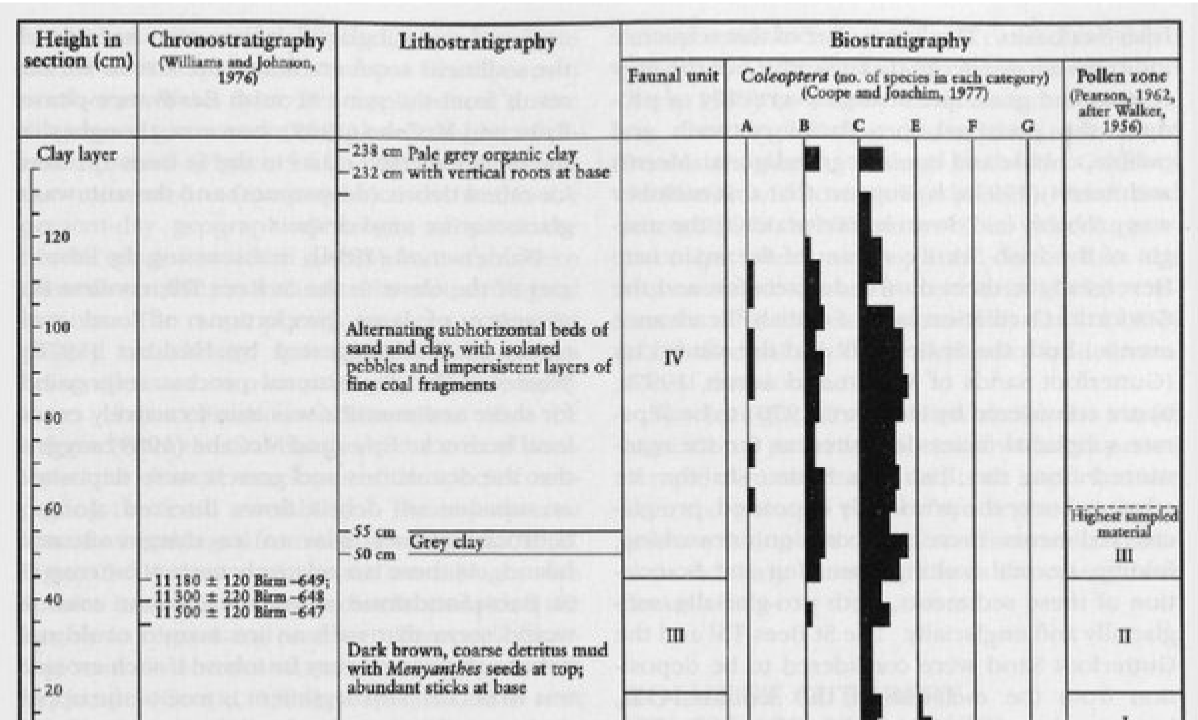
(Figure 5.58) The lithostratigraphical succession at St Bees.



(Figure 5.59) Balanced cross-section for the St Bees cliff section (after Eaton, 1997).



(Figure 5.60) Late-glacial pollen diagram from St Bees: A, individual trees; B, individual shrubs; C, individual land herbs; D, summary curves for land flora; individual taxa of uncertain ecology (after Walker, 1966b).



(Figure 5.61) Synoptic diagram of chronostratigraphy, lithostratigraphy and coleopteran biostratigraphy at St Bees (after Cope and Joachim, 1980). A, boreal and montane species whose normal range is above the tree-line; B, boreal and montane species whose normal range also includes the upper part of the coniferous forest; C, widespread species whose normal range is north of central Britain; D, cosmopolitan species; E, widespread species whose normal range is *south of central Britain; F, southern species whose northern limit of distribution just reaches, or fails to reach, southern England; G, southern European species.*