

Main Late Devensian glaciation of north-west England

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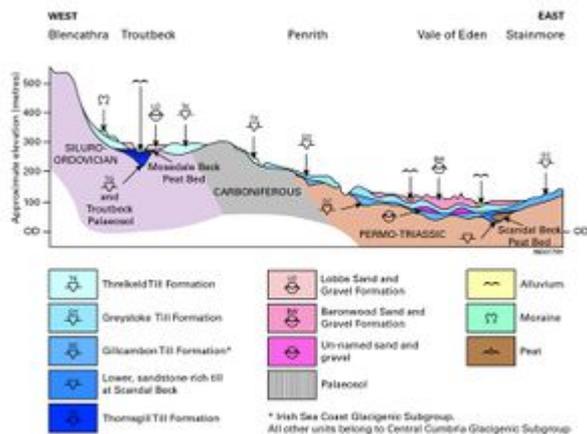
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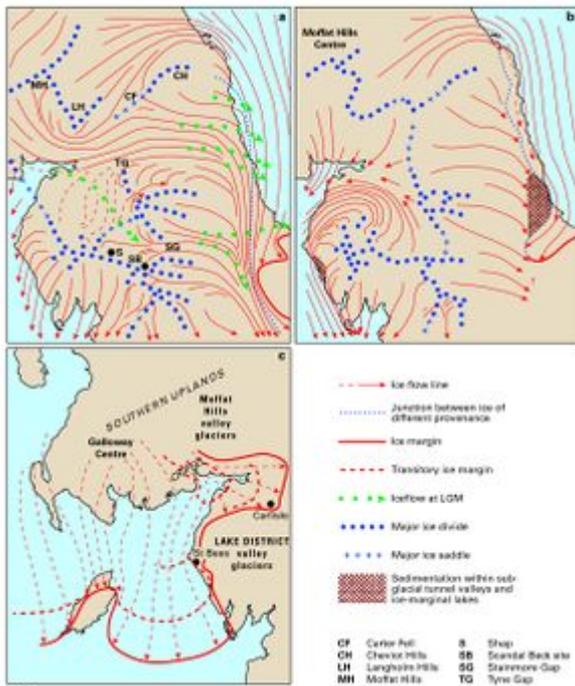
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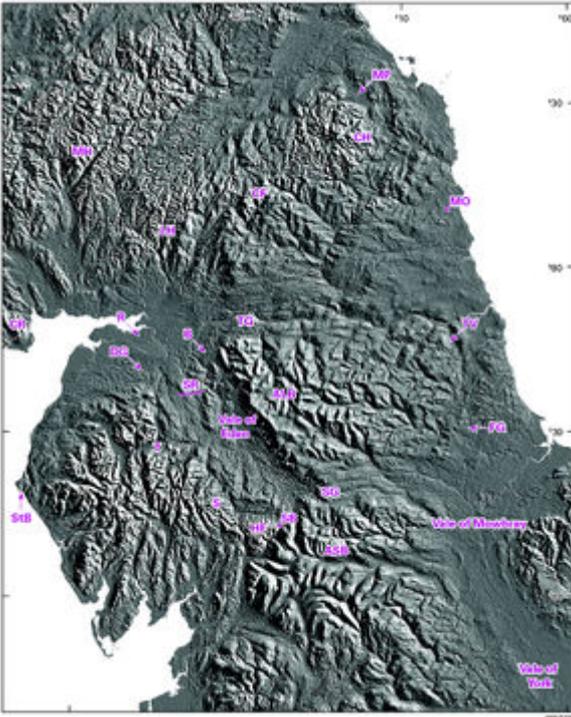
Introduction



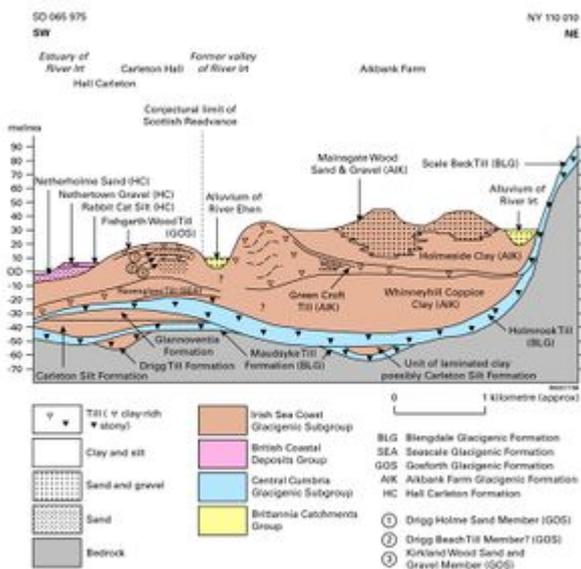
Schematic transect between the northern Lake District and the Vale of Eden showing lithostratigraphical relationships. P916100.



Speculative reconstructions of the last ice sheet. a At about the Last Glacial Maximum (LGM): 28–22 ka BP, but when Scottish ice had ceased flowing across Stainmore, and Scandinavian ice had advanced into the central North Sea Basin, forcing ice from the Pennines and Tweed Basin to flow into the Vale of York. b Following a major glacial reorganisation involving ‘drawdown’ and ‘headward scavenging’ of the Irish Sea ice stream into the Solway lowlands and Vale of Eden. Exact timing and correlation of events is unknown, but North Sea ice pushed farther into the Teesside lowlands once ice from the Lake District ceased flowing across Stainmore. Subglacial glaciofluvial deposition probably occurred within tunnel valleys in the Durham lowlands prior to the creation of Glacial Lake Wear. c Scottish ice advances into the Solway lowlands following retreat of ice sourced in the Lake District. Multiple readvances affect the Isle of Man and the west Cumbrian coast. P916098.

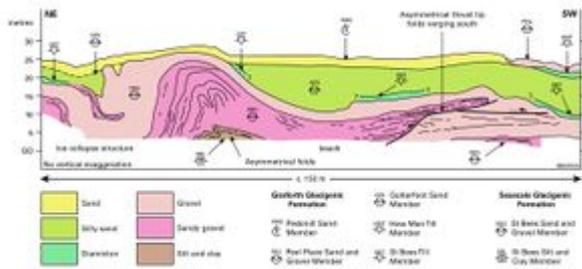


NEXTMap Digital Surface Model (1.2 m vertical resolution) (NEXTMap Britain elevation data from Intermap Technologies). ALB Alston Block; ASB Askrigg Block; B Brampton Kame Belt; CF Carter Fell; CH Cheviot Hills; CR Criffel; DG Dalston Gap; FG Ferryhill Gap; HF Howgill Fells; LH Langholm Hills; MH Moffat Hills; MO Maidens Hall opencast site; MP Millfield Plain; R Rogen moraine; S Shap Fell; SG Stainmoor Gap; SR Scottish Readvance limit at Carlisle; SB Scandal Beck interstadial site; StB St Bees Moraine; T Troutbeck interglacial sites; TG Tyne Gap; TV Team Valley. (P916120).



Schematic transect across lower Wasdale, Lake District, showing relations of the

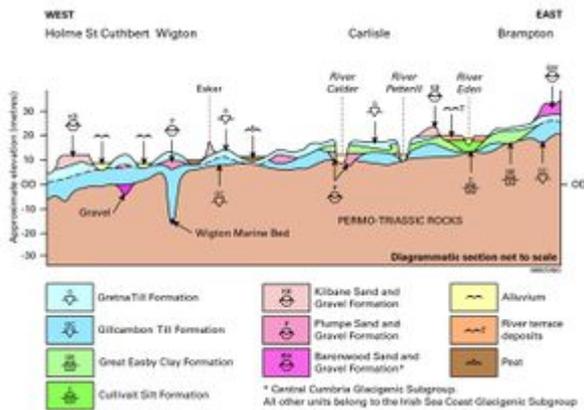
lithostratigraphical units. P916097.



Sketch of part of the push moraine exposed south-east of St Bees beach. P916101.



Scraithole Vein in Scraithole Mine, West Allendale, Northumberland. The vein cuts the Namurian Great Limestone, and consists predominately of witherite with small quantities of sphalerite and numerous clasts of limestone wall rock. (Photo T F Bridges, 1983; P601083).



Schematic transect across the Solway lowlands and Carlisle showing lithostratigraphical relationships. P916102.

Erratics of granodiorite and wacke from the Southern Uplands occur in discrete units of till within bedrock depressions and in the cores of some drumlins in the Vale of Eden (P916100). A Devensian age is likely, as the tills are not particularly weathered. The stratigraphical position and fabric of these diamictons, which are assigned to the Gillcambon Till Formation, indicate that Scottish ice flowed up the Vale of Eden, across the Stainmore Gap and towards Teesside and the Vale of York. It was joined in the upper Vale of Eden by ice flowing from the northern Lake District. Scottish ice also flowed eastwards through the Tyne Gap. The timing of this 'Early Scottish Advance' is unclear, but it probably occurred during the LGM, if not earlier in the Devensian (P916098)a. Scottish ice was subsequently displaced from the Vale of Eden, though ice sourced in the Galloway Hills continued to flow through the Tyne Gap for a while, where it was joined by ice flowing from the northern Lake District. Ice funnelled across Stainmore from both the Lake District and Cross Fell, to create the drumlins of the Stainmore Suite. The ice would have reworked previously deposited tills containing Scottish clasts. Ice apparently did not cross the Howgill Fells. The absence of Scottish erratics within the mountainous parts of the Lake District, and the pattern of its glaciated valleys, suggests that throughout the MLD glaciation it was occupied by a local ice cap with radial outlet glaciers.

The shape and distribution of elongate drumlins in the Vale of Eden and around the north of the Lake District (P916120), together with the composition of glacial erratics, indicate unambiguously that ice subsequently flowed down the Vale of Eden, swinging to the west around the northern Lake District and thence into the Irish Sea basin (i.e. in the opposite direction to the earlier situation). From the northern Lake District towards the Solway lowlands at Carlisle there is a northward progression of drumlin style — from spindle-shaped, through less elongate forms, to transverse rogen moraines — that apparently indicates a diminishing rate of flow towards the lower ground where ice was thickest. The glacial reorganisation, which possibly followed partial deglaciation, is also recorded between Appleby and Brough, where the Stainmore Suite of drumlins is overprinted by the younger Howgill Suite, created by ice flowing northwards from an important ice divide crossing the Howgill Fells. The reorganisation is probably recorded stratigraphically at the Scandal Beck interglacial site where, despite possible glacetectonic disturbance, the sandstone-rich till overlying the peat bed, and the uppermost limestone-rich till, have been correlated with the Stainmore and Howgill suites of drumlins respectively.

The upper till deposited in the Vale of Eden following the reorganisation is named the Greystoke Till Formation. Although most clasts are derived from the Lake District and Edenside, it contains some Scottish erratics, especially towards the north, that have probably been reworked from the deposits of the Early Scottish Advance. The Lowca Till and Ravenglass Till members of the Seascale Glacigenic Formation were probably formed at this time in west Cumbria, by ice swinging around

the north of the Lake District, picking up clasts from the Cumbrian Coalfield. The tills are generally red, extremely compact and stony; they are up to 10 m thick, but locally infill buried valleys 70 m deep. In lower Wasdale, the Ravenglass Till rests on diamictons dominated by Borrowdale Volcanic Group lithologies (Holmrook Till Member) ([P916097](#)), indicating that locally sourced ice from the Lake District was displaced southwards. An increase in the proportions of Scottish erratics in tills occurring toward the top of several multi-till sequences in west Cumbria indicates that Scottish ice eventually became even more dominant.

Extensive deposits of glaciofluvial sand and gravel were laid down in the Tyne Gap and Vale of Eden following the ice sheet reorganisation (Baronwood Sand and Gravel Formation). They occur as ice-marginal fans, flat-topped plateaux, mounds, ridge systems and terraces. Fans and plateaux commonly include sequences that coarsen upwards from laminated silt and clay, through fine- and coarse-grained sand to cobble gravel, indicating that they were deposited as deltas within ice-marginal lakes or ice-walled enclaves within stagnant ice. Ridge systems commonly include cores of cobble gravel partially overlain and surrounded by sand and gravel that fine upwards, an assemblage that is typical of eskers formed subglacially. Terraces and benches are generally formed by dense gravel, laid down as glaciofluvial outwash. All deposits include lenses of, and are locally capped by, red gravelly diamicton. The 'Brampton Moraine Belt' east of Brampton exemplifies this suite of landforms. It is an ice-marginal, glaciofluvial complex bounded by ice-contact slopes that face west or north-west and includes the Hallbankgate Esker, which extends towards a major subglacial drainage channel within the Tyne Gap ([P916120](#)).

There are numerous glacial drainage channels around the Vale of Eden, including a splendid series that descends northwards obliquely down the western slopes of the North Pennine escarpment. Most channels were formed in the vicinity of the ice margin at transitory positions of actively retreating ice. They record progressive lowering of the ice surface in conjunction with frontal retreat, which led to eventual separation of ice emanating from the Lake District and Scotland with the formation of intervening lakes (higher levels of 'Glacial Lake Carlisle'). Although some channels within the Vale formed subglacially beneath stagnating ice where steady-state, dendritic, meltwater channel systems developed, in general the ice probably remained active during retreat.

There is a recurrent conclusion in the older literature that one or more major glacial readvances of Scottish ice occurred across the Solway lowlands and the coast of west Cumbria during the later stages of the last glaciation ([P916098](#)). Several limits have been postulated for the main event, the Scottish Readvance, that extend across the Irish Sea, link with the Bride Moraine in the north of the Isle of Man and continue into Ireland, but none has proved sustainable. Nevertheless, the readvance concept has recently regained support following the discovery of fresh evidence in the Solway lowlands, west Cumbria, the Isle of Man and Ireland.

Evidence for a readvance of Scottish ice was first reported from the Carlisle district and subsequently two readvances, the 'Gosforth Oscillation' and the subsequent Scottish Readvance *sensu stricto* were established in west Cumbria. It has since been confirmed from extensive investigations in west Cumbria that the Gosforth Oscillation event, in particular, witnessed widespread deposition of fine-grained sediment in the lower reaches of the Eden Valley and in lower Wasdale (Seascale and Aikbank Farm Glacigenic formations) ([P916097](#)). The traditional view is that these bodies of sediment were deposited in proglacial lakes dammed at the eastern margin of Irish Sea ice, but alternatively they may have been laid down subglacially within 'tunnel valleys'. Whatever their origin, the deposits were then overridden and glaciectonically disturbed during several subsequent local glacial readvances of Irish Sea ice that caused minimal subglacial erosion, yet laid down thin, widespread units of sandy or clayey diamicton containing well-dispersed pebbles and shell fragments. This thinly bedded and heterogeneous package of sediments constitutes the Gosforth Glacigenic Formation. There are minority views that tills of the Gosforth Glacigenic

Formation are either solely the products of proglacial, cohesive debris flows or, more contentiously, are glaciomarine mud drapes.

The type area for the Scottish Readvance is the St Bees Moraine, where there are splendid cliff sections through proglacially tectonised deposits ([P916101](#)) & ([P666380](#)). However, the regional significance of the Scottish Readvance at St Bees remains problematic. It has generally been correlated with the creation of the Bride Moraine on the Isle of Man, which has been recently linked with Heinrich Event 1. The Gosforth Oscillation, and likely subsequent readvances, all occurred in response to expansions and contractions of the Irish Sea ice stream, which repeatedly encroached on the Cumbrian coast to override ground previously glaciated by ice emanating from inland sources.

Fine-grained glaciolacustrine deposits of the Great Easby Clay Formation were laid down in the Carlisle area when deglaciation was interrupted by a readvance of Scottish ice, such that ice occupied the Solway Firth and blocked drainage within the Solway lowlands ([P916102](#)). The levels of 'Glacial Lake Carlisle' thus formed may have first been dictated by the heights of overflow channels within the Tyne Gap, exploiting previously formed subglacial channels, and later by ice-marginal channels to the south-west of Carlisle. A misfit valley linking the modern rivers Caldew and Wampool by way of the Dalston Gap, south-west of Carlisle, functioned as a major glacial spillway ([P916120](#)). The Great Easby Clay Formation includes dark reddish brown clays, silts and very fine-grained sands that are generally thinly laminated and locally varved. The laminated deposits contain sparse dropstones and convolute bedding; slump and water-escape structures are common. Sands and gravels deposited in and around the lake to the north have been assigned to the Plumpe Sand and Gravel Formation.

The Great Easby Clay and Plumpe Sand and Gravel formations (formerly known as the 'Middle Sands') overlie an extensive landscape unconformity developed on till containing Scottish clasts and probably laterally equivalent to the Gillcambon Till of the Vale of Eden. The age of the unconformity is unknown, but it possibly formed during a partial deglaciation of the MLD ice sheet following the LGM, but before the Scottish Readvance at St Bees.

The glaciolacustrine and glaciofluvial sediments that were deposited in and around Glacial Lake Carlisle, and other more ephemeral lakes, have been disturbed glacitectonically and are capped by red diamictons of the Gretna Till Formation, which is dominated by Scottish clasts. A readvance of Scottish ice clearly occurred there, but synchronicity with the 'Scottish Readvance' at St Bees seems unlikely, especially since parts of the Great Easby and Plumpe formations have been incorporated within drumlins sculptured by ice that flowed from the Vale of Eden as well as Scotland. The glacial limit of the readvance of Scottish ice across Lake Carlisle is not clear, but it probably lies just to the south of the city where new NEXTmap imagery ([P916120](#)) reveals an abrupt termination of a suite of low, south-north orientated, elongated drumlins.

Deposits of glaciofluvial sand and gravel were laid down during the final retreat of Scottish ice. Several parallel eskers were created by meltwaters that flowed subglacially towards an ice margin in the vicinity of the Dalston Gap overflow channel. They are draped on drumlins formed earlier by ice that flowed in the opposite direction. A prominent terraced plateau at Holme St Cuthbert, north of Maryport, subsequently formed as a delta at the margin of ice lying to the north-west ([P916120](#)).

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