

“ the radical ‘Scottish Readvance’ model has been both challenged and supported by glaciologists and biostratigraphers ever since the 1920s ”

The fertile agricultural pastures of the Solway Lowlands conceal a fascinating story of repeated glaciation and sea level change. Using field evidence from the Carlisle Plain and Cumbrian coast, geological surveyors of the 1920s developed a ground-breaking model for a regional readvance of ice from the Southern Uplands of Scotland during the deglaciation of the last (Main Late Devensian) ice sheet. This radical

deposited a suite of sediments distinct from those of the main glaciation. Glaciofluvial and glaciolacustrine deposits accumulated in the coastal lowlands of Cumbria during the initial deglaciation, to be overridden by ice during later glacial readvances. Each readvance caused minimal recognisable subglacial erosion, yet laid down a thin, widespread mantle of diamicton forming the upper unit of a ‘tripartite’

The Quaternary history of the Solway

Revisiting the Scottish Readvance

by Andrew McMillan

‘Scottish Readvance’ model has been both challenged and supported by glaciologists and biostratigraphers ever since.

A much needed, newly completed revision survey of the Quaternary geology of eastern Dumfries and Galloway (last surveyed in the 1880s) and northern Cumbria vindicates the readvance theory but has highlighted intriguing, and as yet unexplained, patterns of ice sheet movement.

Ice ages

Although most evidence from the sedimentary record in the region relates to the last glaciation, with its maximum at about 22 000 years ago, it is clear that the Solway has been subjected to multiple glaciations. The lithological characteristics of the clasts and matrix enable tills and glaciofluvial sands and gravels of Southern Uplands provenance (derived from Lower Palaeozoic wackes) to be distinguished from those derived from Carboniferous and Permo-Triassic sources of the Irish Sea, Solway, Dumfries, Lochmaben and Carlisle basins.

Evidence for the readvance

Surveyors concluded in the 1920s that at least one major expansion of Scottish ice

stratigraphical sequence (till–outwash sand and gravel–till). It is the upper diamicton which has been the subject of debate. Is it the product of lodgement at the base of an ice sheet or an ablation, englacial or periglacial product? The ‘tripartite’ sequence is preferentially preserved around Gretna in south-trending buried valleys, perpendicular to the flow of ice. In this area, red sandy till overlies a sequence of glacitected red fine-grained sands and silts resting on gravel, which in turn rests on stiff red clayey till (see photo left). Soft sediment structures reveal the sands were saturated at the time of deformation implying that the overriding ice was ‘warm based’.

The origin and distribution of the ‘tripartite’ sequence has been difficult to explain satisfactorily. In the past many dismissed it as illusory, but there can no longer be any doubt that locally two discrete units of red till are indeed separated by a sequence of red sands and gravels. Sedimentological characteristics show that the upper till was deposited subglacially and resulted from at least a local glacial readvance as the ice sheet actively retreated across the Carlisle Plain and eastern Dumfriesshire. The timing of such events is unknown, because no datable interbedded organic deposits have yet been found.



J Merritt, BGS © NERC

The Plumpe Farm section, Gretna where stiff, red, pebbly sandy clay diamicton (deformation till) overlies glaciofluvial sand. Between the two is a 0.5 m thick ‘glacitected’ with gradational contacts in which the sand becomes increasingly compact, sheared and clayey upwards and has a wavy, subhorizontal tectonic lamination. Spade 0.9 m long.

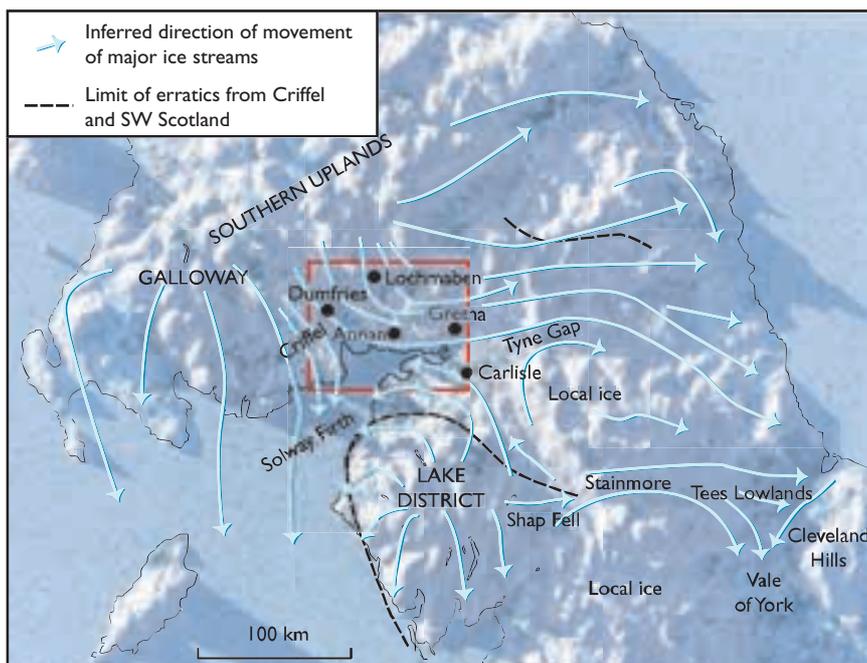
Pattern of glaciation and deglaciation

Remotely sensed data (satellite imagery and air photos), striae, lithologies and erratics confirm the patterns of ice flow (see map, *right*, and cover). A southerly flow of glacier ice from the dissected Southern Uplands mountains is highlighted by streamlined drumlins and rock-cored ridges in the low ground of the Dumfries and Lochmaben basins. Nearer the present coast, ice flowed southwards and south-eastwards from an ice centre in the granitic mountains of Galloway. Crossing the high ground of Criffel (a notable source of granodiorite erratics in northern England), ice proceeded eastwards as evidenced by moulded streamlined rock ridges south of Dumfries and an exhumed boulder pavement in lodgement till near Annan.

Topographical differences, coupled with the final easterly ice flow direction, may account for the selective preservation of 'tripartite' sequences within south-trending valleys, as at Gretna. Also, these sequences are commonly preserved within drumlins, thus supporting the 'Boulton' theory of drumlin formation. In contrast, the sediment preservation potential within the Nith valley, Dumfries, is low because the final flow of ice was aligned down, not across, that valley.

South of Gretna, under the Carlisle Plain, till and outwash sequences conceal Late Palaeozoic and Mesozoic strata. West of Carlisle, drumlinised till and outwash deposits overlie deformable strata of the Mercia Mudstone and Lias groups. Glacitectonised mudstones were recently well exposed in the temporary excavations for the foot-and-mouth disease mass burial site at Watchtree, Great Orton. The drumlins indicate that ice flowed from the Lake District valleys along the Eden Valley and deflected westwards, towards the Irish Sea basin, and eastwards, through the Tyne Gap.

Patterns of deglaciation are well demonstrated by sediments and landform in the Solway district. In the Nith valley, active retreat of the glacier occurred in a north-west direction towards pinning points (bedrock highs). Inland, the lodgement till is an overconsolidated sandy diamicton with wacke and sandstone clasts. At low elevations, the till is overlain by discontinuous spreads of cobble gravel,



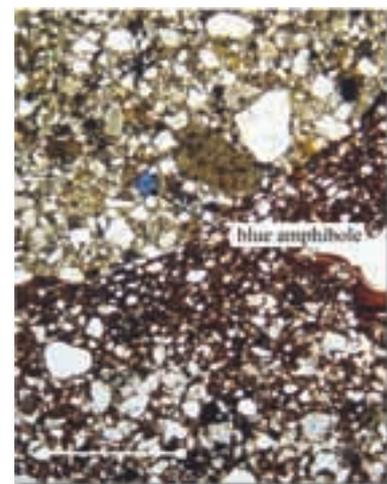
Generalised pattern of ice flow directions.

capped by a discontinuous thin, gravelly flow till, forming kames, kame terraces and north-west-trending eskers. Beyond the retreating ice-front sand, silt and clay with dropstones were deposited in ephemeral glacial lakes. These deposits are overlain by sandar spreads of sand and pebbly gravel. Local ice readvance resulted in morainic mounds of folded and sheared glaciolacustrine sediments.

Future directions

The Solway district appears to have acted as a point of confluence between easterly moving Southern Uplands ice and northerly directed Lake District ice. The interaction of these ice sheets is still poorly understood, and questions concerning their dynamics and relative timing remain to be resolved, offering much scope for future research.

Beyond revealing the glacial history, the survey is providing new insights on the post-glacial history of the Solway — a research area of relevance for climate change and sea level studies and flood risk assessments. Other objectives include the provision of a better understanding of the three-dimensional architecture of glacial sequences for a wide range of applications, including hydrogeological and geotechnical characterisation and aggregate resource assessment. ■



Thin section of an impregnated block taken near the base of the deformation till shown in the photograph (opposite). Close-up of a rounded clast of wacke sandstone (top of picture) in a matrix of sandy diamicton (bottom of picture). The sandstone contains a detrital blue amphibole. Cross-polarised light; scale bar is 1 mm long. [Sample N2843].

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