Nigg Bay

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Highlights

The deposits exposed in the coastal section at Nigg Bay comprise a sequence of tills and glaciofluvial sediments. These provide important evidence for establishing the sequence and patterns of glaciation, including the interactions of different ice masses, in eastern Scotland.

Introduction

The site at Nigg Bay [NJ 965 046] is a section on the coast immediately to the south of Aberdeen. It shows a succession of till and glaciofluvial deposits and has long been regarded as a classic locality for glacial stratigraphy. The deposits at Nigg Bay have been discussed in the literature for almost a century, with debate focused on the number of separate ice advances and readvances that may be represented. The deposits have been described by Jamieson (1882b), Bremner (1928), Simpson (1948), Synge (1963), Chester (1975), McLean (1977) and Munro (1986), and also discussed in more general reviews by Charlesworth (1956), Synge (1956), Clapperton and Sugden (1972, 1977) Murdoch (1977) and Hall and Connell (1991).

Description

The section occurs on the south side of Nigg Bay in a suite of deposits infilling a former valley of the River Dee (Simpson, 1948; Law, 1962; Munro, 1986). Borehole evidence on the shore and seismic evidence from the bay show this channel to descend to below –40 m OD and extend at least 1 km offshore. Six distinctive beds have been recognized in the exposure (Jamieson, 1882b; Bremner, 1928; Simpson, 1948; Synge, 1963; Chester, 1975):

6.	Head	0.5–1.0 m
5.	Gravels	1–3 m
4.	Red sands with laminated silts and clays	1–2 m
3.	Red till	2–3 m
2.	Grey till	10 m
1.	Sands and gravels	3–6 m

The horizontally bedded sands and gravels (bed 1) are seen only at the southern end of the section and rest on a weathered granite–gneiss. Jamieson (1882b) described their thickness as 10–20 ft (3–6 m), but only part of this bed has been exposed in recent years. Diagnostic erratics include ultrabasic material which can be traced to the Belhelvie igneous complex 10 km to the north-north-west, larvikite and rhomb porphyry (see Bremner, 1922) inferred to be of Scandinavian origin, and andalusite schist (Read *et al.,* 1923; Bremner, 1928, 1934a, 1939b; Synge, 1963). Armoured till balls have also been found incorporated in the gravels (E. R. Connell, unpublished data). A 5 m thick layer of sands and gravels, underlying a till, was encountered at the base of a borehole at Nigg Bay, and this may correlate with the basal sands and gravels of the cliff section (Munro, 1986).

Unconformably overlying the lower sands and gravels is a tough, compact, grey till up to 10 m thick (bed 2). It contains local erratics predominantly of granite and gneiss and in its lower part the clasts have a south-south-west to north-north-east preferred orientation (Synge, 1963). This unit correlates with a widely occurring local till in the Aberdeen area (McLean, 1977; Murdoch, 1977). There is a transition upwards from the grey till to the red till (bed 3). Elsewhere, in pipeline trench exposures near Aberdeen, these two tills have been seen interbedded (Chester, 1974, 1975; Murdoch, 1975, 1977; Munro, 1986). Apart from its colour the red till is distinguished by the presence of Old Red Sandstone conglomerate and volcanic erratics and by a more northerly preferred stone orientation than the grey till (Jamieson, 1882b, 1906; Synge, 1963). The source of this material was traditionally held to be the Old Red Sandstone rocks of

Strathmore and the volcanic rocks between Lunan Bay and Montrose (Jamieson, 1906; Munro, 1986). However, heavy-mineral studies by Glentworth *et al.* (1964) point to the floor of the North Sea as an additional source, a possibility in fact admitted by Jamieson (1882b). The red till forms part of a suite of red deposits extending along the northeast coast of Scotland from south of Stonehaven to north of Peterhead (Jamieson, 1882b; Bremner, 1916b; Synge, 1956; McLean, 1977; Murdoch, 1975, 1977; Hall, 1984b; Auton and Crofts, 1986; Munro, 1986).

The sands (bed 4) above are reddish brown in colour and contain thin bands of laminated red clays. Southwards these sands merge into and are succeeded by gravels (bed 5) containing the same erratics as the red till. There is no sharp junction between the sands and gravels, implying that they are probably contemporaneous (Simpson, 1948). The gravels are coarse and poorly bedded with lenticles of sand, and in their upper part (bed 6) are highly shattered and cracked (Jamieson, 1882b), typical of a head deposit. Simpson (1948) suggested that sorted coarse and fine fractions in this deposit represented stone stripes and polygons seen in section. The gravels have a hummocky surface expression (termed 'morainic' by Simpson (1948), and continue inland and to the south of Nigg Bay where they are associated with kettle holes in the Loirston area [NJ 940 010].

Interpretation

The erratic content of the lower sands and gravels led most workers to postulate early glaciation from the north or north-west contemporaneous with the presence of Scandinavian ice in the North Sea Basin. Bremner (1928) suggested that the lower sands and gravels consisted in part of deposits from his first glaciation from the north that were subsequently reworked by meltwater. Simpson (1948) also thought that they were derived from the earliest glacial deposits of the area, which might be associated with Bremner's first ice-sheet (Bremner, 1928, 1934a, 1938). From the distribution of erratics in north-east Scotland, Bremner inferred ice movement during this glaciation from north-west to south-east across this area; for example, near Aberdeen he recorded boulders thought to be from the northern Highlands and the Elgin area, and, near Inverbervie, boulders from Huntly. At the same time Scandinavian ice in the North Sea Basin blocked the escape of Scottish ice to the east and, as the former approached from the north-east, it impinged on the coast at Aberdeen and in Kincardineshire. It was possible, he argued, that the shelly indigo-coloured till in the Ellon area (see Bellscamphie) reported by Jamieson (1906) and thought by him to have been transported from the north during the first glaciation was in fact related to the Scandinavian ice moving onshore (Bremner, 1928, 1934a). Clapperton and Sugden (1977), however, have advocated the need for caution in interpreting igneous and metamorphic 'erratics' since more recent work on bedrock geology in north-east Scotland has shown greater diversity of rock types and more widespread distribution of the sources of indicator types. Moreover, in the light of evidence from the North Sea (Stoker *et al.,* 1985), Hall and Connell (1991) considered it unlikely that Scandinavian ice ever reached the coast of Scotland, and that the erratics of presumed Scandinavian origin were ice-rafted and subsequently entrained by Scottish ice.

Synge (1956, 1963) also proposed early glaciation from the north-east (Scandinavian glaciation) followed by an expansion of Scottish ice (Greater Highland Glaciation) moving south-south-east along the Aberdeenshire coastal area, but he thought the lower sands and gravels at Nigg Bay were beach deposits derived from the earliest till rather than glaciofluvial deposits, as implied by Bremner (1928) and stated by Read *et al.* (1923). Possibly the armoured till balls in the lower sands and gravels at Nigg Bay are the reworked remnants of an early till. Further evidence for an early north-west to south-east ice movement was provided by Murdoch (1975, 1977) from clast-fabric studies of an argillaceous lodgement till found locally in the Aberdeen area but not seen at Nigg Bay. This till was considered (Murdoch, 1975; Munro, 1986) to be of Late Devensian age, but Sutherland (1984a), on the basis of evidence for ice-free conditions to the north-west of Aberdeen (Hall, 1984b), suggested that the north-west to south-east glaciation that deposited this till must have pre-dated the Late Devensian.

There is general agreement among all workers that the red and grey tills were broadly contemporaneous and reflect the interaction of two distinctive ice masses (Jamieson, 1882b, 1906; Bremner, 1928, 1934a, 1938; Simpson, 1948, 1955; Synge, 1956, 1963; Clapperton and Sugden, 1972, 1977; Murdoch, 1975, 1977; McLean, 1977; Auton and Crofts, 1986; Munro 1986; Hall and Connell, 1991). The grey till with its local erratics was deposited by ice moving down the Dee Valley; the red till, with its Old Red Sandstone erratics, was deposited by Strathmore ice moving north-east along the coast. Both Jamieson and Bremner related the two tills to their respective second ice-sheets and suggested that the local

Dee ice had receded before the red till was deposited. Most workers now agree, however, that the two ice streams coalesced, although the initial influx of ice from the west weakened and was succeeded by the Strathmore ice (Hall and Connell, 1991). Synge interpreted the deposits as being the product of his Moray Firth–Strathmore Glaciation of Devensian age; Simpson, Clapperton and Sugden, McLean and Murdoch assigned them to the Late Devensian ice-sheet.

The presence of Scandinavian ice in the North Sea Basin has often been cited as the reason for deflection of the Strathmore ice along the east coast of Scotland. Recent studies of offshore sediments, however, indicate that the Scottish and Scandinavian ice-sheets did not meet or coalesce during the Late Devensian (Jansen, 1976; Cameron *et al.,* 1987; Sejrup *et al.,* 1987; Hall and Bent, 1990). Alternative explanations for the flow pattern must therefore be sought. Following the suggestion of Hall and Bent (1990) for the Moray Firth area, one possibility is that a change in flow pattern developed where ice from sources in the south-west Highlands emerged from valleys with rigid rock beds on to the potentially mobile beds formed by the thick sediments of the lowlands and nearshore coastal zone. That such changes can theoretically occur has been demonstrated for the Late Weichselian Laurentide ice-sheet (Fisher *et al.,* 1985).

Influenced by the presence of red clay deposits at Tullos and to the north of Aberdeen, Jamieson envisaged a marine or lacustrine depositional environment for the Nigg Bay tills. However, their undoubted glacial nature was established by later investigators. Recent ideas suggest they may have been formed by melt-out and flow processes (McLean, 1977; Murdoch, 1977).

The origin of the upper gravels (bed 5) has been more contentious. Agassiz (see Jamieson, 1874, p. 323) suggested that the gravel mounds were moraines, a view endorsed by Buckland (1841a). According to Jamieson (Jamieson, 1865, 1874, 1882b, 1906) they were the ice-marginal moraines of his third and last glaciation during which ice advanced down the Dee Valley and extended just offshore, forming an 8 km wide ice-front between Nigg Bay and Belhelvie to the north of Aberdeen where another suite of gravel mounds occurs. He also argued that there had been a longer and possibly warmer time interval between his second and third ice-sheets than between the first two. Bremner (1928, 1934a, 1938) proposed a similar interpretation, but placed the northern limit of the ice near the Ythan. He also related the gravels to his third ice-sheet, the existence of which he had established elsewhere largely on the basis of supposedly marginal melt¯water channels.

Charlesworth (1956) included the upper morainic gravels as part of his Highland Glaciation, which he recognized as a separate readvance after the last ice maximum, with a local ice limit near Belhelvie. Synge (1956, 1963), too, thought the gravels were ice-marginal deposits, part of what he called a lame moraine' marking the limit of a separate glacial event of pre-Loch Lomond Stadial age, the Aberdeen Readvance. Synge correlated this glacial event with the Perth Readvance (Simpson, 1933), but Sissons (1965, 1967a) later linked it with features in the south of Scotland to mark another event known as the Aberdeen–Lammermuir Readvance. However, subsequent re-examination of the evidence has failed to substantiate the existence of these readvances (Sissons, 1974c).

In important contributions, Simpson (1948, 1955) was first to perceive that the upper 'morainic' gravels did not represent a separate ice readvance but were contemporaneous with the last ice-sheet to cover the area. The gravels contained the same erratics as the red till and were not derived by ice readvance from the west. Moreover, he suggested that the gravels were not moraines, but were glaciofluvial kames which formed a continuous suite of deposits extending from south of Nigg Bay to the River Ythan. In places the kames were overlain by till and he proposed that many were of englacial origin. Subsequent work by Clapperton and Sugden (1972, 1975, 1977) and Murdoch (1975, 1977) has substantiated Simpson's interpretation. These authors argued that the continuity of glaciofluvial landforms across the supposed limit of the Aberdeen Readvance reflected the integrated subglacial hydrological system of a single ice-sheet. Moreover, the continuity of the landforms and the undisturbed nature of the red and grey tills implied contemporaneous deposition and ice decay during a single glaciation. Furthermore, ice-wedge casts occur both within and outside the supposed Aberdeen Readvance ice limit (Sissons, 1974c; Gemmell and Ralston, 1984), and therefore their distribution cannot be used to support the readvance concept, as was suggested by Synge (1963).

The Nigg Bay section is a key reference locality for the interpretation of the glacial history of the eastern Highland boundary area. At least two distinct glaciations *can* be inferred from the sequence of deposits: a pre-Devensian glaciation

represented by the lower sands and gravels, and a Late Devensian glaciation by the overlying succession of tills, sands and gravels. The succession of Late Devensian deposits illustrates particularly well the complexity of depositional environments that may be associated with a single glacial episode. Nigg Bay also has significant potential for further research, for example on the sedimentol-ogy of the deposits. In addition, further study of Nigg Bay and other multiple till sections will provide useful field evidence of changing ice-sheet flow patterns that can be used to test and refine theoretical models of ice-sheet growth. For example, Nigg Bay clearly illustrates that early expansion of inland ice from the mountains and valleys to the west was succeeded by a dominant flow of ice from sources in the south-west Highlands.

Conclusion

The deposits at Nigg Bay are important for interpreting the glacial history of the Eastern Highland Boundary area. They have a long history of research and illustrate the interaction of ice masses from different source areas. Although it has been proposed that the deposits were formed by different ice-sheets in a series of separate glaciations, current interpretations ascribe most of the sequence to the Late Devensian glaciation (approximately 18,000 years ago).

References