Current model for glaciation and conclusions from 150 years or research, Quaternary, Cainozoic of north-east Scotland

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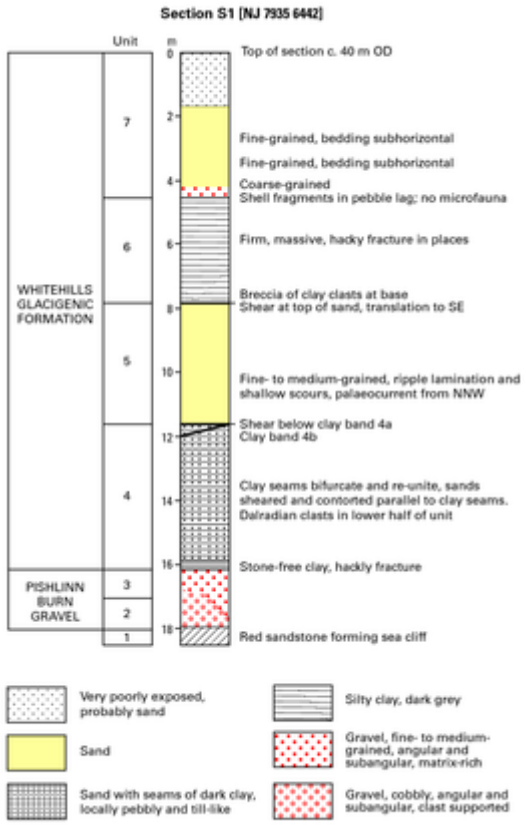
Contents

The current model for the glaciation of NE Scotland

Early stage of the Main Late Devensian glaciation (c. 28 to c.22 ka BP)



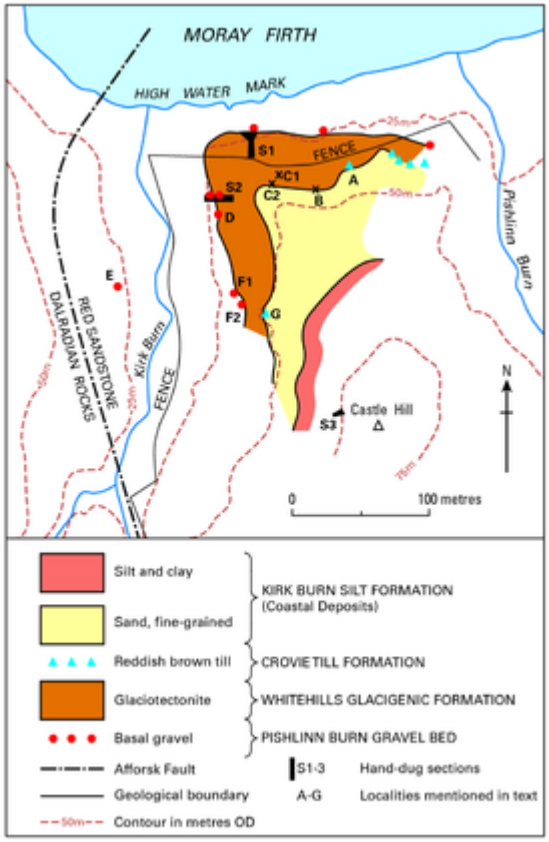
Lithological log of Section S1 at Castle Hill (after Peacock and Merritt, 1997). P915307.

NE Scotland was overwhelmed entirely by ice early during this period (Hall and Bent, 1990; Peacock and Merritt, 1997; Whittington et al., 1998) (P915307). A major ice stream occupied the Moray Firth, flowing across deformable muds and Mesozoic sediments. West Highland-sourced ice flowed both north-eastwards along Strathmore, towards the North Sea, and down the Spey Valley, towards the Moray Firth (Sutherland and Gordon, 1993). The relatively sluggish, and probably locally cold-based East Grampians ice cap occupied the rest of the region. The Moray Firth ice stream encroached upon the coastal lowlands of Moray and Banffshire, and probably crossed the Buchan Plateau towards Aberdeen (Hall and Jarvis, 1995). The southerly deflection of ice was probably caused by the presence of Scandinavian ice in the central North Sea. The power of the Moray Firth ice stream subsequently waned in comparison with ice sourced inland, allowing it to flow northwards and eastwards towards the coasts.

Partial glacial retreat during a mid-Late Devensian interstadial (c.22-18 ka BP)

Judging from the NW Fennoscandian record of Olsen (1997) and Sejrup *et al*. (2000) (Figure 5.16) there was significant glacial retreat during the cold, dry, Hamnsund Interstadial. This probably occurred at about 20 ka BP, although bone fragments at the type locality suggest that it may have occurred earlier, at c.24.5 ka BP (Mangerud *et al*., 1996). It is likely that there was also substantial ice-sheet recession in NE Scotland, when, for example, the East Grampian ice sheet retreated from central Buchan allowing the development of ice-marginal lakes between it and ice remaining at the coast (Figure 5.15). The lower reaches of the valley of the River Deveron, north of Turriff, were possibly blocked at this time by Moray Firth ice causing meltwaters to flow south and east, first via the Towie spillway, near Fyvie, then into the valley of the River Ythan (Figure 5.15).

Later stages of the Main Late Devensian glaciation (18 ka-13 ka BP)



Map of Castle Hill, Gardenstown (after Peacock and Merritt, 1997). P915306.

Although there are no unambiguous records of substantial readvances of the East Grampian ice sheet there is evidence that the Moray Firth ice stream remained active during this period. The moraines at Cross-stone, near Ellon, clearly formed as a result of a late readvance onshore from the North Sea, possibly brought about by Scandinavian ice remaining in the North Sea basin in the form of a low, residual dome. This would have caused ice from Strathmore to be deflected northwards, then north-westwards into Logie-Buchan. However, the central North Sea is thought to have been ice free at this time (Sejrup *et al*., 1994). Moray Firth and Strathmore ice advanced to the position of the Bosie's Bank and Wee Bankie moraines respectively (P915306), possibly contemporaneously with the Tampen Readvance of NW Fennoscandia (Sejrup *et al*., 1994).

The Moray Firth ice lobe probably stood at the entrance of the Moray Firth at about 15 ka BP, where it splayed out and actively disturbed deposits of the glaciomarine St Fergus Silt Formation. There was substantial ponding of meltwater between the slowly retreating East Grampians ice sheet and the more active Moray Firth ice stream (Figure 5.15). Local glacial readjustments led to a minor readvance of the East Grampians ice towards the Banffshire coast following the retreat of the Moray Firth (Peacock and Merritt, 2000). A subsequent oscillation of the Moray Firth ice stream affected the area around Elgin, possibly at about 14 ka BP, and a further one formed the prominent push moraine at Ardersier, near Inverness, at roughly about 13 ka BP (Merritt *et al*, 1995). In the Aberdeen area, substantial ponding occurred between the slowly retreating East Grampian ice sheet and ice offshore (Thomas and Connell, 1984). The lakes, or possibly an arm of the sea, gradually expanded southwards as the two bodies of ice 'un-zipped' in that direction (Simpson, 1954; Aitken, 1991).

Some conclusions from 150 years of research into the glaciation of NE Scotland

The glacial reconstructions published over the past 150 years are clearly conflicting, and some aspects are certainly flawed, but they all contain elements that remain valid. It is salutary that the stratigraphical approach of Jamieson has arguably best survived the test of time. The sequences he described have generally been confirmed in recent site excavations and most of his deductions about the origins of deposits presented in his final paper (1906) are sound. Although there is still doubt about the time span involved, the basic tripartite sequence he first established in the Ellon area still holds, and his evidence supporting the Aberdeen Readvance has not been rejected beyond doubt.

Bremner's final model was not so firmly based on stratigraphy, but his evidence for incursion of Scandinavian ice is compelling (assuming that erratics of Norwegian rhomb porphyry have been corrected identified). Although some of the meltwater channels that he thought were formed at the retreating margin of the last ice sheet contain pre-Late Devensian deposits (eg. Crossbrae) and hence are older features, partially at least, most conform to the pattern of ice retreat that he deduced. Conversely, the evidence does not support Clapperton and Sugden's (1977) model of a regionally-integrated, contemporaneous network of channels forming beneath a warm-based East Grampian ice sheet. Nevertheless, the continuity of channel development is strong evidence in support of full ice cover during the last glaciation of the region. The pattern of ice movement in Clapperton and Sugden's model is in broad agreement with available stratigraphical evidence, although it may be modified in eastern Buchan to take into account the evidence of eastward glacial streamlining (Merritt et al., 2003), rather than south-eastward flow. Furthermore, their flow lines for the Strathmore ice stream do not account for the significant onshore carriage of Permo-Triassic lithologies into eastern Buchan.

The concept of 'Moraineless Buchan' was apparently supported by the discovery of a unit of peat within a glacial drainage channel at Crossbrae (Table *), high on the Moss of Cruden (Whittington et al., 1998). This *Crossbrae Peat Bed* (Table *) appeared to rest on till deposited by ice flowing from the west and it was overlain by gelifluction deposits, not by till. The interstadial pollen record it contained together with bulk radiocarbon dates suggested that the peat had formed early in the Late Devensian. The site seemed to provide crucial evidence that 'inland series' tills in the area pre-dated the Late Devensian and that central Buchan had indeed not been glaciated during that period (Sutherland, 1984; Connell and Hall, 1987). However, on re-examination in 1992, the peat was found to rest on bedrock and to be overlain by coarse gravels of possible glaciofluvial origin (Whittington *et al*., 1998). Furthermore, new dating and palaeoenvironmental evidence from the peat indicated that it was formed most probably during the Early Devensian, during OIS 5c or 5a (Table 8.1). The coarse gravel unit was probably, but not unequivocally Late Devensian in age. Evidence from Crossbrae clearly could no longer be used to support arguments that parts, or all, of Buchan escaped glaciation in the Late Devensian

It now seems unlikely that ice-free areas existed anywhere in Scotland during the Main Late Devensian glaciation, including Caithness and the islands of Orkney and Lewis (Hall and Whittington, 1989; Hall, 1995; Ballantyne et al., 1998; Fabel et al., 2012). Present models consequently return to earlier reconstructions of extensive ice sheet glaciation in the Late Devensian, such as Sissons (1976) and Boulton *et al*. (1977, 1985), with Scottish ice terminating at, or close to, the continental shelf to the north and west of Scotland and covering most of the northern North Sea basin (Hall and Bent, 1990, Sejrup *et al*., 1998, 2000, Merritt et al., 2003).

Full ice cover in Buchan during the Late Devensian is implied by the projection of ice surface profiles from terminal moraines of probably Late Devensian age in the Outer Moray Firth (Hall and Bent, 1990) and by evidence that the Scottish and Scandinavian ice sheets coalesced in the northern North Sea between 28 and 22 ka BP (Sejrup *et al*., 1994, 2000). Furthermore, the existence of raised glaciomarine silts and a raised beach at St Fergus **(Table *),** radiocarbon dated to 14-15 ka BP (Hall and Jarvis, 1989; Peacock, 1997), implies the previous removal of a thick ice cover, because considerable isostatic depression would be required for such sediments to be laid down during a period of low global sea level. A consequence of accepting a more widespread glaciation between 28 and 22 ka BP is that there must have been considerably more glacio-isostatic depression of the land in NE Scotland, and hence higher relative sea levels, than determined by Lambeck (1993b) from numerical, geophysically-based modelling.

Fabel D, Ballantyne CK, Xu S. 2012. Trimlines, blockfields, mountain-top erratics and the vertical dimensions of the last British-Irish Ice Sheet in NW Scotland. *Quaternary Science Reviews* **55**: 91-102.

References

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