Site 26 Burn of Benholm

The shelly pebbly clays and peat lenses exposed beneath the Mill of Forest Till at the Burn of Benholm, provide new insights into the glacial history of eastern Scotland prior to the Late Devensian. The peat lenses are remnants of an Early Devensian interstadial deposit of OIS 5c or 5a age. Amino-acid ratios indicate that shells in the underlying clays are of OIS 9 age or older, and the fabric and composition of the shelly sediments are consistent with their emplacement as glacially deformed rafts of marine sediment. The rafts were transported onshore when Scandinavian ice occupied the North Sea basin, during a pre-Late Devensian glacial episode.

Exposures in the banks of the Burn of Benholm, 14 km north of Montrose (Map 11), have for many years revealed a Quaternary sequence that includes a dark grey clay containing fragmentary marine shells, overlain by reddish brown till. In one exposure lenses of peat and organic silt intervened between the units (Plate 27); most of the lenses were incorporated within the red till, near to its base (Campbell, 1934; Donner, 1960, 1979).

Particular controversy has focused on the age and origin of the shelly clay and on the age and biostratigraphical significance of the peat lenses (Gordon, 1993d). The shelly clay has been interpreted as a till deposited by ice moving onshore, at a time when Scottish and Scandinavian ice sheets coalesced in the North Sea basin (Campbell, 1934; Bremner, 1938; Donner, 1960). More recently, Sutherland (1981) proposed that the shelly sediment is an in situ cold water marine deposit formed as a result of significant isostatic loading during an Early Devensian glaciation.

A pollen assemblage from peat collected by Campbell was subsequently described by Bremner (1943) as containing thermophilous tree pollen, and interpreted by him as indicating an interglacial environment. Later pollen analyses of the peat lenses, however, showed spectra dominated by non-arboreal types representing herb communities (Donner, 1960, 1979). This suggested an interstadial, rather than interglacial origin for the peat, which Donner (1960) initially interpreted as being of Late-glacial (Windermere) Interstadial age. He also proposed that the overlying red till was emplaced by landslipping, or gelifluction during the Loch Lomond Stadial a comparable origin to that proposed here for the Knockhill Wood succession (see above). A sample of the Burn of Benholm peat (Hel–1098) subsequently yielded a radiocarbon age of greater than 42 000 BP, which led Donner (1979) to reinterpret its age as being Early or Middle Devensian and the red till as being of the Main Late Devensian glaciation.

Because of the conflicting interpretations of the origin of the shelly clay and of the palaeoenvironmental conditions represented by the pollen in the peat deposits, a reinvestigation of the deposits at Burn of Benholm has been undertaken recently (Auton et al., 2000). The work included new excavations (Figure A1.34) adjacent to the stream sections first described by Campbell. One of these, trial pit BBP 4, revealed a new exposure of peat lenses beneath the base of the red till.

The Burn of Benholm site [NO 795 691] comprises a series of stream sections and trial pits at about 45 m OD along the Burn of Benholm. The lithostratigraphy is summarised in (Table A1.17). The sections and trial pits clearly show the Mill of Forest Till overlying Benholm Clay Formation in the manner described by Campbell (1934). In some of the exposures a sharp, undulating contact, varying from subhorizontal to steeply dipping, occurs between the two formations. In other sections, such as BBP 2, a zone of shearing and churning occurs with red-brown till mixed with a more gravelly unit at the top of the Benholm Clay. In trial pit BBP 4 sheared and folded lenses of peat and sandy silt occur within this gravelly unit. In section RC 1 deformed units of Mill of Forest Till and the underlying Birnie Gravel abut a knoll of andesite bedrock.

Clast orientations measured from the Mill of Forest Till all display tightly clustered fabrics suggesting subglacial deposition and indicate a north-easterly to east-north-easterly direction of ice movement. In contrast, eastwardly dipping stratification and north-westwardly dipping sheared contacts within the Benholm Clay, together with clasts of Mesozoic and Palaeozoic rocks are compatible with glacitectonic transport of the unit from offshore.

A sparse assemblage of fragmentary bivalve molluscs (some of which are 'polished' and striated) has been recovered from the Benholm Clay Formation. The assemblage included *Arctica islandica, Macoma balthica, Cersatoderma edule*

and *Mya* sp. and is of boreal to low arctic aspect, but suggests no particular age other than, broadly 'Late Pleistocene'. Samples from the Benholm Clay have also yielded rich palynomorph assemblages, which were completely dominated by Early Carboniferous, Early and Late Cretaceous and Palaeogene forms (Harland, 1993). This reworked material was probably derived from the North Sea basin. Small numbers of Quaternary dinoflagellate cysts were also recorded. Two main taxa were recognised: *Protoperidinium* sp. and *Bitectatodinium tepikiense*. Both are indicative of north-temperate to arctic, cold-water marine environments, possibly in close proximity to ice (Harland, 1983; Dale, 1985). A sparse assemblage of agglutinating foraminifera was found in two samples from the clay (Wilkinson, 1993). All of the foraminifera are considered to be reworked and, although their age is unknown, it is unlikely that they are younger than Palaeogene. The paucity of indigenous microfossils and the abundance of reworked material are consistent with interpretation of the clay as a former offshore deposit, reworked and transported onshore by ice.

Pollen analyses were carried out by M J C Walker on four samples of organic material from the Burn of Benholm Peat Bed exposed in Trial Pit BBP 4 and are reported fully in Auton et al. (2000). The pollen spectra in all four samples are broadly similar and are comparable to those reported by Donner (1960, 1979), although a wider range of taxa has been recorded. Collectively, the pollen evidence points to an open tundra vegetation of damp heath and grassland, with patches of low scrub, and isolated stands of tree birch probably in more sheltered localities. This confirms the view that the site probably does not contain an interglacial record; rather, it represents an interstadial episode with summer temperatures slightly below those of the present day.

A distinctive feature of the pollen spectra is the occurrence of a number of grains resembling *Bruckenthalia spiculifolia*. *Bruckenthalia* pollen has been found at a number of interglacial sites in north-west Europe (e.g. Turner, 1970; Menke and Behre, 1973; Phillips, 1976; Hall, 1980), although the species appears to be more typically associated with Early Weichselian to Early Devensian Interstadial deposits (Whittington, 1994). Indeed, *Bruckenthalia spiculifolia* has been cited as a biostratigraphical marker for Early Weichselian Interstadials (Pons et al., 1992). Bruckenthalia has also been found at the Crossbrae Farm and Camp Fauld (Moss of Cruden) sites described above, which may also be of Early Devensian age (Whittington et al., 1993, 1998; Whittington, 1994).

Three sets of 'total' amino-acid D/L (D-alloisoleucene: L-isoleucene) ratios have been determined on fragmentary shells of *Arctica islandica* collected from the Benholm Clay Formation in section RC 1. They are 0.37 (AAL 2950), 0.37 and 0.38 (AAL 2952) and 0.34 ± 0.024 (LOND 400). The third analysis (Lond 400) is regarded as the most accurate.

Conventional radiocarbon dating was carried out on a single bulk sample taken from a lens of the Burn of Benholm Peat in the upper part of the Benholm Clay Formation, between 2.0 and 2.3 m depth in trial pit BBP 4. The acid-insoluble residue was subdivided into its alkali soluble (humic) and alkali insoluble (humin) components for independent age measurement. The humic carbon sample, SRR–5201a, gave a radiocarbon age of greater than 50 850 ^{14}C years BP; the humin sample, SRR–5201b, one of greater than 50 600 ^{14}C years BP. Both dates are older than the upper limit of the radiocarbon chronology and provide a minimum (Mid-Devensian) age for the Benholm Peat.

The interstadial affinity of the pollen, the presence of *Bruckenthalia spiculifolia* and infinite radiocarbon dates from the Burn of Benholm Peat Bed, all suggest that the peat lenses are remnants of an Early Devensian interstadial deposit of OIS 5c or 5a age or older (Table 7).

Amino-acid ratios from the fragments of *Arctica islandica* suggest that the shells within the Benholm Clay Formation are of OIS 9 age or older. The fabric and composition of these shelly sediments are consistent with their emplacement as immature deformation till, formed by partial homogenisation of glacially transported rafts of marine sediment. The amino-acid ratios suggest that this till was deposited by ice during a post-OIS 9/11 glaciation. It may be derived from offshore sediments within the Coal Pit Formation, which is of probable Saalian to Weichselian age (Stoker et al., 1985), or from the Ling Bank Formation (which contains an interval of Holsteinian age), or correlate with a till within the Fisher Formation, of supposed Saalian age (Gatliff et al., 1994) (Chapter 5, (Figure 33)). Folded and sheared contacts between the shelly deposits, the peat lenses and the Mill of Forest Till indicate that the fossiliferous sediments were glacitectonised during the Main Late Devensian glaciation, when ice from within Strathmore overrode the site from the south-west.

(Table A1.17) Lithostratigraphy in the vicinity of the Burn of Benholm.

Lithostratigraphical unit	Lithology	Typical thickness (m)
Drumlithie Sand and Gravel Formation *	Rounded cobble gravel	up to 1.20
Mill of Forest Till Formation*	Stiff, moderate reddish brown, sandy clayey stony diamicton, containing clasts derived from the Devonian bedrock of Strathmore	up to 1.30
Burn of Benholm Peat Bed†	Peat and humic clay as sheared lenses in overlying till and underlying clay	up to 0.15
Benholm Clay Formation†	Stiff, olive-grey, calcareous, silty clay and clayey diamicton; with well dispersed clasts and fragments of marine shells, including Arctica islandica (L.). Clasts include basalt, gneiss, troctolite, limestone (including chalk), shale, flint and jet, as well as Lower Old Red Sandstone lithologies	up to 3.00
Birnie Gravel Formation‡	Moderate brown, clayey gravel	up to 3.00
Bedrock	Andesite	

- † Logie-Buchan Drift Group
- ‡ East Grampian Drift Group
- Mearns Drift Group

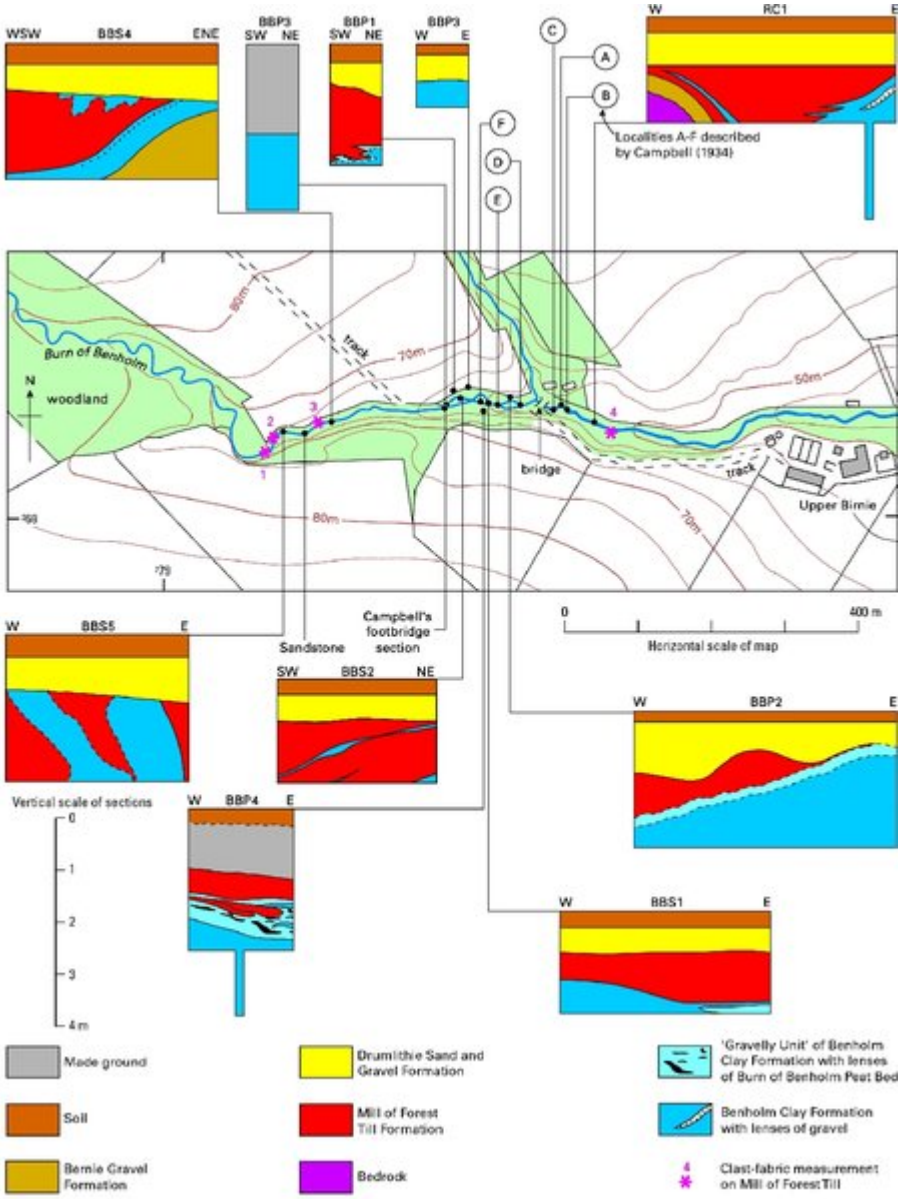
(Table A2.1) Sand and gravel resource assessment surveys in north-east Scotland: primary data sources.

Mineral Assessment Report name, number and date	Area (km^2)	1:25 000 resource	Boreholes	Trial pits and natural sections	Resistivity soundings	Sampled workings
Garmouth (41) [1979]	54	1	57	31	0	3
Peterhead(58) [1981]	258	1	67	19	0	11
Elton (76) [1981]	343	2	61	39	0	15
Aberdeen (146) [1986]	660	3	77	72	0	17
Inventrie, Dunecht, Banchory & Stonehaven (148) [1988]	398	2	54	51	43	38
Strachan, Auchenblae & Catterline (149) [1990]	274	2	38	55	22	35
Total	1987	11	354	297	65	119

References

(Map 11) Glacial and glaciofluvial features and the distribution of glacigenic deposits on Sheet 67 Stonehaven.

(Plate 27) Sheared lens of the Burn of Benholm Peat Bed within olive grey shelly clay and diamicton (Benholm Clay Formation) in trial pit BBP4, at the Burn of Benholm site north of Johnshaven (Appendix A, 26). The shelly deposits are overlain by red-brown diamicton of the Mill of Forest Till Formation (D4879).



(Figure A1.34) Excavations and measured sections at the Burn of Benholm.

Lithostratigraphical unit	Lithology	Typical thickness (m)
Drumlithie Sand and Gravel Formation*	Rounded cobble gravel	up to 1.20
Mill of Forest Till Formation*	Stiff, moderate reddish brown, sandy clayey stony diamicton, containing clasts derived from the Devonian bedrock of Strathmore	up to 1.30
Burn of Benholm Peat Bed†	Peat and humic clay as sheared lenses in overlying till and underlying clay	up to 0.15
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Birnie Gravel Formation‡	Moderate brown, clayey gravel	up to 3.00
Bedrock	Andesite	

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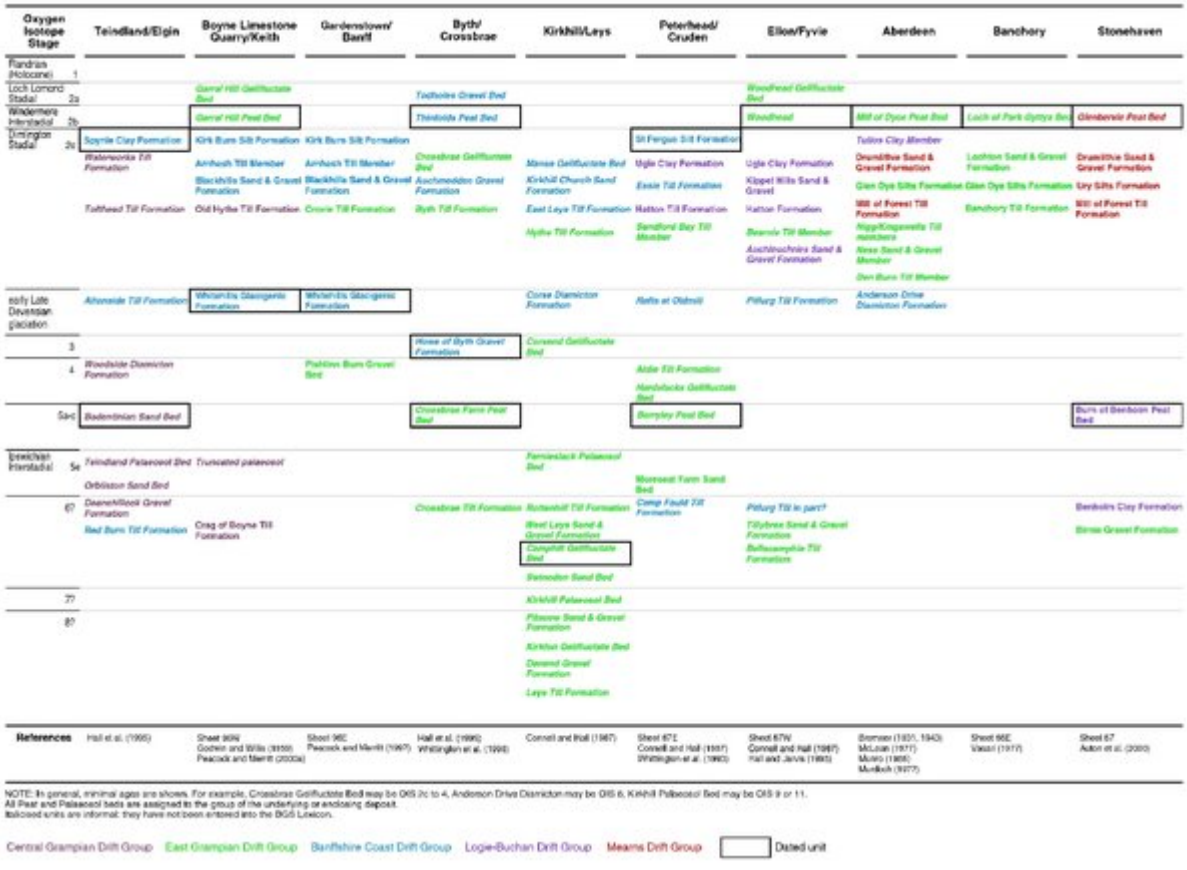
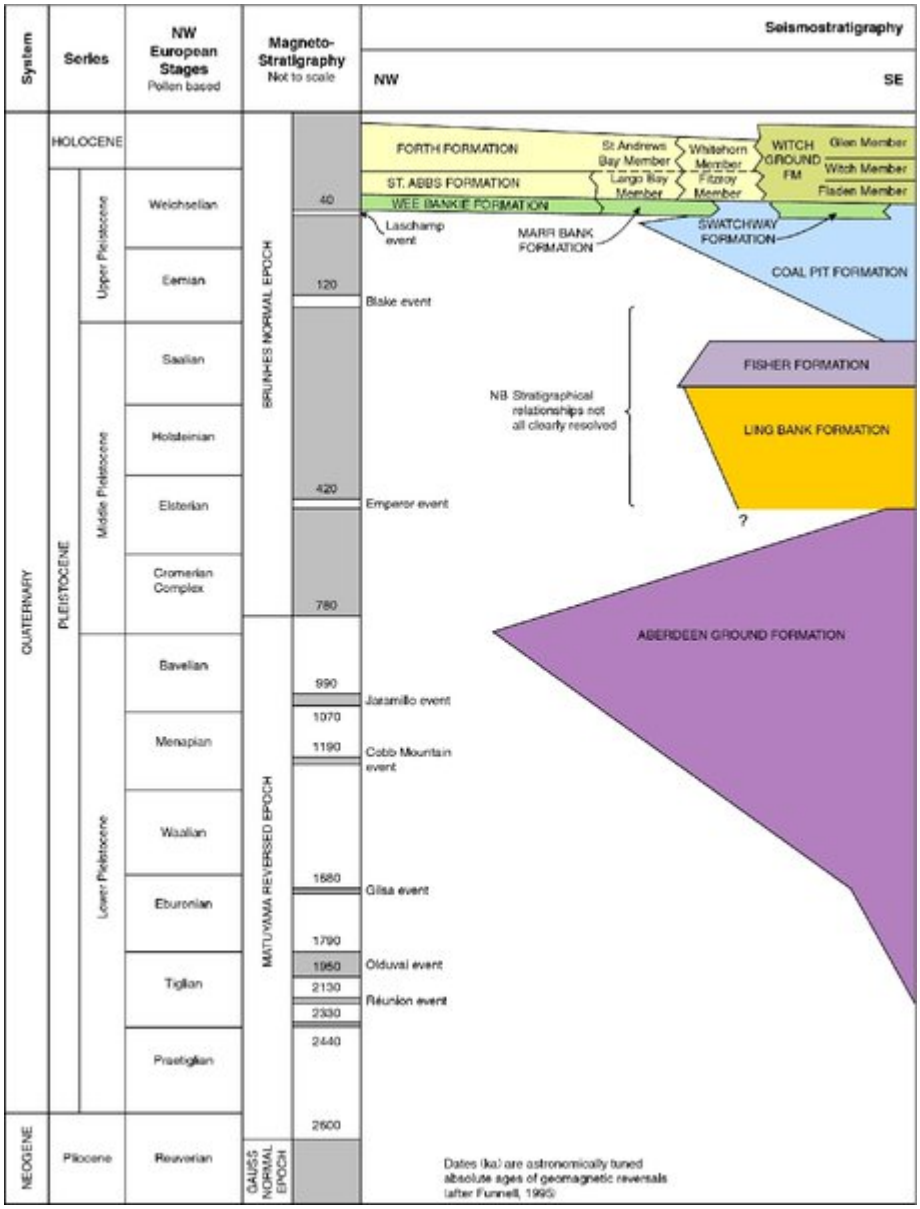
(Table A1.17) Lithostratigraphy in the vicinity of the Burn of Benholm.



(Table 7) Correlation of lithostratigraphical units in north-east Scotland.



(Figure 33) Quaternary stratigraphy of the central North Sea (from Gatliff et al., 1994).