BOYNE QUARRY

J. E. Gordon

OS Grid Reference: NJ613659

Highlights

The superficial deposits exposed at Boyne Quarry include a sequence of multiple tills and ice-marginal lake deposits. These provide important evidence for interpreting the glacial history of the Moray Firth coastal area and the associated depositional environments.

Introduction

Boyne Quarry (NH 613659), *c.* 7.5 km west of Banff, is important for a succession of deposits demonstrating the glacial stratigraphy of the southern coast of the Moray Firth. Two, or possibly three tills occur (Peacock, 1966), and the basal one has been correlated with pre-Devensian weathered tills known elsewhere in north-east Scotland. The exposure is a comparatively recent one and does not appear in the extensive early literature on the glaciation of the Moray Firth coast; the only published references are by Peacock (1966, 1971a) and Connell and Hall (1984b). However, as one of the few localities showing an extended succession of deposits which help to clarify the controversial stratigraphic sequence in the region, it is an important reference site.

Description

The Boyne Quarry section was described by Peacock (1966) and comprises the following sequence:

6.	Peaty soil	0.6 m
5.	Horizontally bedded silt, sand and gravels	0–1.2 m
4.	Grey, silty till with gabbro boulders derived from the Huntly basic complex	1.5 m
3.	Dark grey, clayey till with shell fragments	3.0–4.6 m
2.	Dark grey, shelly silt and clay, in part till-like and in part laminated, with pockets of shelly gravel especially at the base	1.5–3.7 m
1.	Light-brown till	0–3.7 m

The till of bed 1 is considerably decomposed in comparison with the deposits above it. It comprises subrounded pebbles and cobbles of quartzite, with lesser amounts of granite, calc-schist and gabbroic rocks, in a gritty, clayey matrix. Apart from the quartzites, most of the clasts are decomposed. According to Connell and Hall (1984b), the weathering profile is truncated and the till surface covered by a thin (0.02 m) layer of brown silt, and by fine sand and gravel infilling shallow depressions. Subsequent examination (J.D. Peacock, unpublished data) has, however, shown that the till also includes fresh cobbles and boulders of gabbro and that the weathered appearance may partly reflect the incorporation of weathered bedrock. Such weathered bedrock was formerly seen below bed 1 on the south side of the quarry.

Further work has shown that the clay (bed 2) contains Foraminifera, and that the crushed mollusc shells reported earlier are single valves of *Nuculana pernula* (Müller) (J.D. Peacock, unpublished data). Connell and Hall (1984b) have suggested that bed 2 can be subdivided into a lower unit of sheared and interbedded layers of red and brown silt and fine sand, and an upper unit of dark grey, clayey till. Peacock (1966) also noted that the site was apparently unaffected by solifluction.

Interpretation

The glacial deposits of the Moray Firth coast have a long history of investigation, which provides the context for interpreting the sequence at Boyne Quarry. Early accounts drew attention to the presence of anomalous beds of clay containing Jurassic fossils (Christie, 1830; Prestwich, 1838a, 1840; Brickenden, 1851) and exposures of shelly stratified sands, gravels and clays, notably at Gamrie (see Castle Hill) and King Edward (Prestwich, 1838b, 1840; Chambers, 1857).

Martin (1856) described many of the characteristics of the glacial drift of the area and attempted to explain it in terms of debris transported by sea ice during a great submergence. From his observations on the distribution of erratics and patterns of striae, Mackie (1901) deduced ice movement initially from the interior towards the north-east, but it gradually becoming diverted towards the east and south-east by ice in the Moray Firth, in the first instance by ice from the Northern Highlands then by ice from Scandinavia.

The most significant early contribution, however, was that of T.F. Jamieson, who, in the course of his investigations of the glacial phenomena of Scotland, described many of the exposures and characteristics of the Moray Firth drift and pieced together a stratigraphic sequence for the area (Jamieson, 1858, 1865, 1866, 1874, 1882b, 1906, 1910). His more important observations included:

1. detailed descriptions of the King Edward and Castle Hill sections and identification of arctic shell assemblages (Jamieson, 1858, 1865, 1866, 1906);

2. confirmation of Chamber's (1857) report of a dark grey boulder clay overlying the shelly silts and sands at King Edward (Jamieson, 1866, 1906);

3. identification of a dark, bluish-grey shelly clay between Cullen and Banff, with erratics derived from westerly sources and Jurassic material from the Moray Firth sea floor (Jamieson, 1866, 1882b, 1906);

4. the eastwards continuation of the dark shelly clay to Peterhead and its interdigitation with the red clay of the east coast of Aberdeenshire (Jamieson, 1866, 1906);

5. the inference, from erratics and striae, that ice moved from west to east (Jamieson, 1866, 1906).

From these observations, and work elsewhere in Scotland, Jamieson (1865, 1906) deduced the glacial succession in the Moray Firth area as: (1) early glaciation from the north and west (based on evidence in the Ellon area only), (2) main glaciation with ice from the west succeeding ice moving down Strathspey, (3) as the ice melted away, submergence of the coast and deposition of the dark shelly clay and shelly sands contemporaneous with the red deposits of eastern Aberdeenshire, and (4) less extensive glaciation from the west, responsible for boulder clays (on top of the shelly clays and sands), and equivalent to the Aberdeen moraines (see Nigg Bay).

Unfortunately, Jamieson's interpretations were constrained by a rigid conceptual model requiring all "clays' with shells, including those which he definitely recognized as boulder clays, to be deposited in glaciomarine or glaciolacustrine conditions during a great submergence of the coast at the end of the main glaciation. This seems to have arisen from a failure to distinguish between true marine clays and shelly boulder clays. Although Bell (1895a, 1895b, 1895c, 1895d) had clearly questioned the evidence for submergence to explain many of the deposits, his arguments went unheeded in Jamieson's later work (Jamieson, 1906, 1910).

In the Geological Survey Memoir, Read (1923) published a comprehensive review of the field evidence and proposed a fourfold division of the glacial stratigraphy of north Banffshire and north-west Aberdeenshire (sheets 86 and 87):

4. Lateglacial sands and gravels.

3. Upper or northerly drift deposited by ice moving out from Central Banffshire as the south-easterly ice withdrew.

2. The "Coastal Deposits' (see Castle Hill) comprising a suite of sands, clays and gravels, including those at King Edward and Castle Hill, formed in a lake as the south-easterly ice withdrew.

1. Lower or south-easterly drift moving onshore out of the Moray Firth and including the shelly drift and the drift with Jurassic fossils.

This succession, which was based on stratigraphic evidence, striae and erratics, hinged on stratigraphic interpolation since no single exposure showed all the elements of the succession to be superimposed. An important facet of Read's interpretation was that the entire sequence related to a single period of glaciation.

Bremner (1916b) noted the pattern of cross-striations on the south coast of the Moray Firth. Later he agreed with Read's interpretation of two separate ice movements, from the north-west and south, but argued that they represented two distinct glacial periods (his first and second glaciations) (Bremner, 1928, 1934a, 1938, 1943a). Moreover, he proposed the existence of a third ice-sheet, moving from the north-west after deposition of the northerly drift. In support he cited supposedly marginal meltwater channels, evidence from two sections near Rothes and one near Cullen, and glaciofluvial deposits resting on the northerly till and extending from Inverness to Buchan. Bremner (1928) also disputed Jamieson's correlation of the blue shelly till with the red till of the east coast of Aberdeenshire, relating them to separate glaciations.

Charlesworth (1956) supported Bremner's view that the last ice in the Moray Firth area came from the north-west (his Highland Glaciation), and related the "Coastal Deposits' to the final stages of retreat of this ice.

Synge (1956) also accepted that the last ice came from the north-west. However, a problem with Bremner's scheme was that this ice did not leave an extensive till cover, which Synge thought was improbable. Therefore, he proposed that Read's sequence of deposits was inverted and that the lower drift in fact related to the last ice-sheet. Read's upper drift might not be *in situ* but could have been soliflucted on to the "Coastal Deposits' in the very few sections where it was seen to overlie them. Synge suggested that the "Coastal Deposits' might be the equivalent of the Lateglacial gravels (of Read, 1923), noting that the two were never seen in a section together. He concluded, therefore, that the drifts of Banffshire could all be explained in terms of a single glaciation, the last or Moray Firth – Strathmore Glaciation. Erratics from the south were probably incorporated from an earlier drift.

The deposits at Boyne Quarry have an important bearing on these earlier interpretations. Peacock (1966) considered that the weathered till (bed 1) was the relic of a very early glacial episode and that it had undergone prolonged subaerial weathering before deposition of the overlying sediments. It may be of pre-Devensian age (Jardine and Peacock, 1973) and may correlate with the weathered tills reported from Kirkhill (Connell *et al*., 1982; Hall, 1984b) and Kings Cross, Aberdeen (Synge, 1963). However, further work is required to establish the extent to which the apparent weathering reflects the incorporation of previously decomposed bedrock into the till, rather than being *in situ* weathering of the till itself (J.D. Peacock, unpublished data). Peacock (1966) interpreted bed 2 as an erratic and considered it to be the source material for bed 3. Bed 3 appeared to correspond to the shelly till of Banffshire and the "lower or south-easterly drift' of Read (1923). The till of bed 4 was probably part of Read's "upper and northerly drift'. Bed 5 formed part of the "Coastal Deposits'.

The Boyne Quarry section as recorded by Peacock (1966), thus apparently established that Read's till succession was correct at least there, and not inverted as Synge suggested. However, "Coastal Deposits' did not intervene between the tills, and Peacock (1971a) showed elsewhere that they were probably deposited in freshwater lakes during the melting of the last ice-sheet (see Castle Hill).

The apparent confirmation of Read's till succession was subsequently rejected by Peacock (1971a), who reinterpreted the uppermost till unit (bed 4) as simply a separate facies of the immediately underlying shelly till; a view supported by the gradational contact between the two units. Peacock (1971a) favoured the interpretation that the gabbro boulders in the top till

had been incorporated from an earlier till-sheet derived from the south, so that the sequence of deposits above the basal weathered till, comprising beds 2 to 5, was the product of the last ice-sheet flowing from the north-west. An early north to south or south to north ice movement is shown by striations formerly seen on the bedrock surface, but their relationship to the strata in the adjacent drift section could not be ascertained (J. D. Peacock, unpublished data).

The age of the deposits at Boyne Quarry is uncertain. Peacock (1966) considered that the uppermost till (bed 4) and the overlying "Coastal Deposits' (bed 5) were the product of Late Devensian ice-sheet advance and retreat, and the reinterpretation ofPeacock (1971a) indicated that all the deposits except the weathered till (bed 1) were of Late Devensian age. This was also implied by Clapperton and Sugden (1975, 1977) in their consideration of the glaciation of north-east Scotland. Sutherland (1984a), however, suggested that the Late Devensian ice-sheet may have terminated to the west of the site and that hence the last glaciation of this area was pre-Late Devensian. This view was not accepted byHall (1984b), who preferred a Late Devensian age for the last glaciation of the southern Moray Firth coast. Amino acid ratios on shells from sand and gravel horizons immediately overlying the weathered till and from the shelly till imply a Devensian age for the glaciation, but do not yet allow a fuller resolution of the chronological problems (D.G. Sutherland, unpublished data).

Boyne Quarry is a key stratigraphic site demonstrating the much-debated Pleistocene succession on the south coast of the Moray Firth, including the two till units and the "Coastal Deposits' which have formed the basic field evidence for reconstructions of the glacial history of the area. Current interpretations suggest that most of the deposits were produced during a single glacial episode of Devensian age. Boyne Quarry is also particularly significant for one of the few exposures in Scotland of a till which has been considered to be of pre-Devensian age. From a sedimentological viewpoint, Boyne Quarry is also notable in providing a good illustration of the complex sequence of deposits which may be associated with a single glaciation, including a raft of marine clay within shelly till. Finally,Boyne Quarry has significant research potential (Connell and Hall, 1984b). This relates to:

1. the pedological characteristics of the weathered till (bed 1), their origins and the possible correlations with weathered tills elsewhere in north-east Scotland (*cf.* Kirkhill Quarry),

2. the sedimentary characteristics of the deposits in bed 2 and the process responsible for their origin,

3. the significance of the gradational contact between the tills of beds 3 and 4, and the interpretation of these deposits.

Conclusions

Boyne Quarry is a reference site for the ice-deposited sediments of the south coast of the Moray Firth. The sequence includes two, or possibly three tills, one of which may pre-date the Devensian, and demonstrates the main deposits that have been described from the area. Boyne Quarry is therefore important for establishing the pattern of ice movements across the area and also for studies of the formation of the glacial sediments.

Reference list

Bell, D. (1895a) On the alleged proofs of submergence in Scotland during the glacial epoch – II. Clava and other northern localities. *Transactions of the Geological Society of Glasgow*, **10**, 105–20.

Bell, D. (1895b) The shelly clays and gravels of Aberdeenshire considered in relation to the question of submergence. *Quarterly Journal of the Geological Society*, **51**, 472–9.

Bell, D. (1895c) Reply to Professor Hull on the glacial deposits of Aberdeenshire. *Geological Magazine*, dec. 4, vol. 2, 524–7.

Bell, D. (1895d) Notes on ?The Great Ice Age' in relation to the question of submergence. *Geological Magazine*, dec. 4, vol. 2, 321–6; 348–55 and 402–5.

Bremner, A. (1916b) Problems in the glacial geology of northeast Scotland and some fresh facts bearing on them. *Transactions of the Edinburgh Geological Society*, **10**, 334–47.

Bremner, A. (1928) Further problems in the glacial geology of north-eastern Scotland. *Transactions of the Edinburgh Geological Society*, **12**, 147–64.

Bremner, A. (1934a) The glaciation of Moray and ice movements in the north of Scotland. *Transactions of the Edinburgh Geological Society*, **13**, 17–56.

Bremner, A. (1938) The glacial epoch in north-east Scotland. *The Deeside Field*, **8**, 64–8.

Bremner, A. (1943a) The glacial epoch in the north-east. In *The Book of Buchan* (Jubilee volume) (ed. J.F. Tocher). Aberdeen, Aberdeen University Press, 10–30.

Brickenden, L. (1851) On the occurrence of the boulder clay in the limestone quarry, Linksfield, Elgin, N.B. *Quarterly Journal of the Geological Society*, **7**, 289–92.

Chambers, R. (1857) Geological notes on Banffshire. *Proceedings of the Royal Society of Banffshire*, **3**, 332–3.

Charlesworth, J.K. (1956) The late-glacial history of the Highlands and Islands of Scotland. *Transactions of the Royal Society of Edinburgh*, **62**, 769–928.

Christie, J. (1830) Blackpotts Clay, near Banff. *Edinburgh New Philosophical Journal*, **9**, 382.

Clapperton, C.M. and Sugden, D.E. (1975) The glaciation of Buchan - a reappraisal. In *Quaternary Studies in North East Scotland* (ed. A.M.D. Gemmell). Aberdeen, Department of Geography, University of Aberdeen, 19–22.

Clapperton, C.M. and Sugden, D.E. (1977) The Late Devensian glaciation of north-east Scotland. In *Studies in the Scottish Lateglacial Environment* (ed. J.M. Gray and J.J. Lowe). Oxford, Pergamon Press, 1–13.

Connell, E.R. and Hall, A.M. (1984b) Boyne Bay Quarry. In *Buchan Field Guide* (ed. A.M. Hall). Cambridge, Quaternary Research Association, 97–101.

Connell, E.R., Edwards, K.J. and Hall, A.M. (1982) Evidence for two pre-Flandrian palaeosols in Buchan, Scotland. *Nature*, **297**, 570–2.

Hall, A.M. (1984b) Introduction. In *Buchan Field Guide* (ed. A.M. Hall). Cambridge, Quaternary Research Association, 1–26.

Jamieson, T.F. (1858) On the Pleistocene deposits of Aberdeenshire. *Quarterly Journal of the Geological Society of London*, **14**, 509–32.

Jamieson, T.F. (1865) On the history of the last geological changes in Scotland. *Quarterly Journal of the Geological Society of London*, **21**, 161–203.

Jamieson, T.F. (1866) On the glacial phenomena of Caithness. *Quarterly Journal of the Geological Society*, **11**, 261–81.

Jamieson, T.F. (1874) On the last stage of the glacial period in North Britain. *Quarterly Journal of the Geological Society of London*, **30**, 317–38.

Jamieson, T.F. (1882b) On the Red Clay of the Aberdeenshire coast and the direction of ice-movement in that quarter. *Quarterly Journal of the Geological Society of London*, **38**, 160–77.

Jamieson, T.F. (1906) The glacial period in Aberdeenshire and the southern border of the Moray Firth. *Quarterly Journal of the Geological Society of London*, **62**, 13–39.

Jamieson, T.F. (1910) On the surface geology of Buchan. In *The Book of Buchan* (ed. J.F. Tocher). Aberdeen, Aberdeen University Press, and Peterhead, P. Scrogie Ltd, 19–25.

Jardine, W.G. and Peacock, J.D. (1973) Scotland. In *A Correlation of Quaternary Deposits in the British Isles* (eds G.F.Mitchell, L.F. Penny, F.W. Shotton and R.G. West). Geological Society of London, Special Report, No. 4, 53–9.

Mackie, W. (1901) Some notes on the distribution of erratics over eastern Moray. *Transactions of the Edinburgh Geological Society*, **8**, 91–7.

Martin, J. (1856) On the northern drift, as it is developed on the southern shore of the Moray Firth. *Edinburgh New Philosophical Journal*, New Series, **4**, 209–38.

Peacock, J.D. (1966) Note on the drift sequence near Portsoy, Banffshire. *Scottish Journal of Geology*, **2**, 35–7.

Peacock, J.D. (1971a) A re-interpretation of the coastal deposits of Banffshire and their place in the Late-glacial history of Scotland. *Bulletin of the Geological Survey of Great Britain*, **37**, 81–9.

Prestwich, J. (1838a) Observations on the Ichthyolites of Gamrie in Banffshire, and on the accompanying red conglomerates and sandstones. *Proceedings of the Geological Society*, **2**, 187–8.

Prestwich, J. (1838b) On some recent elevations of the coast of Banffshire; and on a deposit of clay, formerly considered to be Lias. *Proceedings of the Geological Society*, **2**, 545.

Prestwich, J. (1840) On the structure of the neighbourhood of Gamrie, Banffshire, particularly on the deposit containing Ichthyolites. *Transactions of the Geological Society*, 2nd Series, **5**,

139–48.

Read, H.H. (1923) The Geology of the country round Banff, Huntly and Turriff. (Lower Banffshire and north-west Aberdeenshire). (Explanation of Sheets 86 and 96). Memoirs of the Geological Survey of Scotland. Edinburgh, HMSO, 240pp.

Sutherland, D.G. (1984a) The Quaternary deposits and landforms of Scotland and the neighbouring shelves: a review. *Quaternary Science Reviews*, **3**, 157–254.

Synge, F.M. (1956) The glaciation of north-east Scotland. *Scottish Geographical Magazine*, **72**, 129–43.

Synge, F.M. (1963) The Quaternary succession round Aberdeen, north-east Scotland. Report of the 6th International Congress on the Quaternary, Warsaw 1961. Vol. 3. Geomorphological Section. Lodz, 353–61.