INCHCOONANS AND GALLOWFLAT

D.G. Sutherland

OS Grid Reference: NO242233

Highlights

Inchcoonans and Gallowflat are important reference sites for the Errol beds, a sequence of fossiliferous estuarine sediments deposited largely in eastern Scotland as the Late Devensian ice-sheet melted. They provide important evidence for the high-arctic nature of the marine environment during the early part of the Lateglacial.

Introduction

The sites at Inchcoonans (NO 242233) and Gallowflat (NO 211202) are located, respectively, 1 km north-west and 4.5 km south-west of Errol, between Perth and Dundee. Both occur in an area of fossiliferous Late Devensian raised estuarine deposits (Errol beds). Inchcoonans comprises a small area of undisturbed deposit adjacent to a former clay pit (now infilled) which provided the type sequence for these deposits; Gallowflat is a working clay pit where the sediments are exposed.

A broad two-fold subdivision of the marine and estuarine sands, silts and clays that were laid down around the Scottish coasts during Late Devensian ice-sheet retreat and in the Lateglacial period has long been recognized; between those deposits containing a restricted high-arctic fauna and those containing a much more diverse boreal to arctic fauna (Jamieson, 1865; Brady *et al*., 1874; Robertson, 1875). This subdivision has been noted to correspond, in general, to the geographical distribution of the deposits, those on the east coast being predominantly high arctic in character and those on the west being predominantly boreal to arctic (Robertson, 1875; Anderson, 1948; Sissons, 1965). Peacock (1975c) proposed the informal terms Errol beds and Clyde beds as referring, respectively, to the high-arctic and the boreal to arctic deposits, this terminology reflecting the locations where the different deposits had been first described in detail. The Inchcoonans and Gallowflat area, by Errol to the north of the Tay Estuary, is therefore the principal reference area of the high-arctic deposits.

At the western end of the Carse of Gowrie on the north of the Tay Estuary the surface of an area of higher ground is mantled by Late Devensian estuarine clays. The clays extend to altitudes of approximately 30 m O.D. and their surface forms a series of terraces, the lowest of which is below 12 m O.D. The western, southern and eastern sides of this higher ground are flanked by Holocene estuarine deposits. A number of clay pits excavated in the upper deposits resulted in the discovery during the last century of marine fossils of species indicative of very cold conditions when the clays were deposited (Jamieson, 1865; Brown, 1867; Brady *et al*., 1874). The most detailed studies were carried out in the Inchcoonans clay pit (now infilled) by Davidson (1932), whose work has in recent years been verified and amplified byPaterson *et al*. (1981) and Graham and Gregory (1981). The deposits at Gallowflat have been described by McManus (1972), MacGregor (1973) and Duck (1990). In addition, the raised shorelines contemporaneous with deposition of the marine clays have been studied in detail by Cullingford (1972, 1977). A summary of the current understanding of these deposits is given inArmstrong *et al*. (1985).

Description

The first systematic description of the stratigraphy of the Inchcoonans clay pit was given by Davidson (1932). He identified three principal units:

3.	Yellowish-brown, sandy clay	2.5–3.0 m
2.	Fine, blue clay, coarsening upwards	1.5–2.1 m
1.	Fine, red clay	over 1.2 m

Pebbles, cobbles and even boulders were scattered throughout the deposits, the surface of which was at about 12 m O.D. More recent investigations have added detail to this outline, and Paterson *et al*. (1981) determined the following sequence (Figure 15.2):

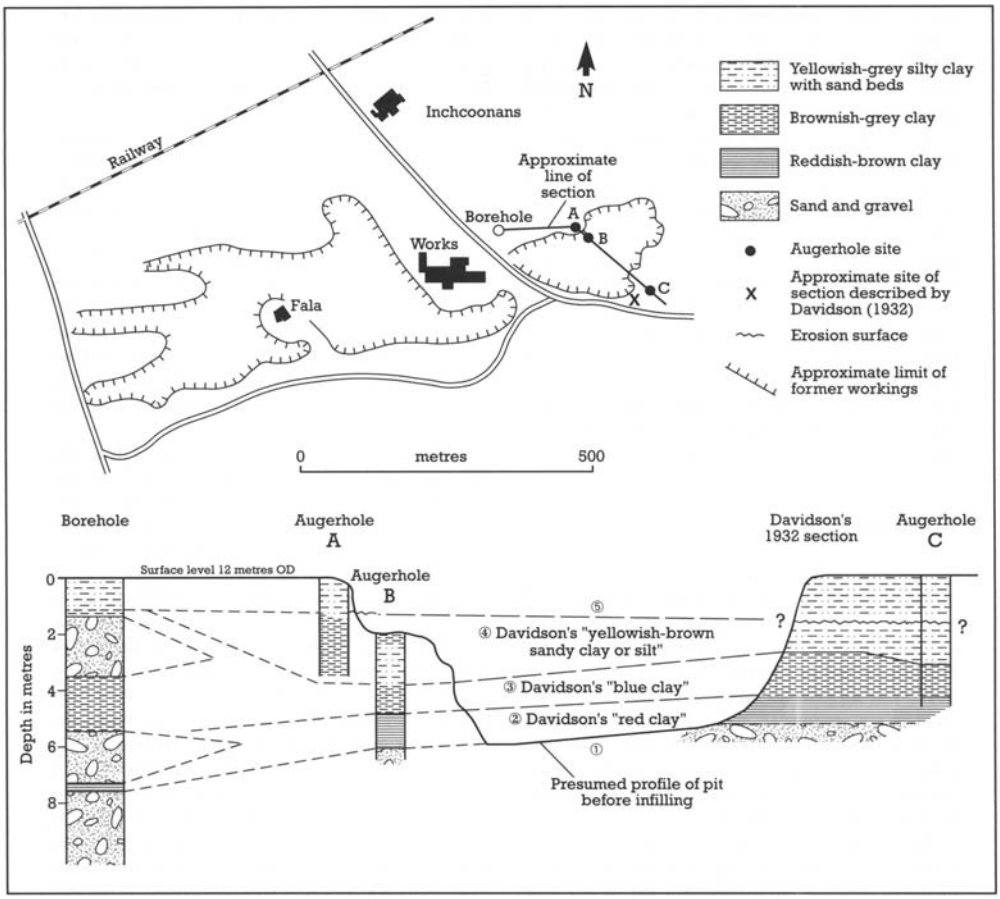

Figure 15.2: Inferred stratigraphy of the Errol beds at Inchcoonans claypit (from Paterson et al., 1981).

5.	Yellowish-grey sandy clay erosion surface	1.0–1.75 m
4.	Yellowish-grey silty clay	1.25–2.9 m
3.	Brownish-grey clay	0.9–1.5 m
2.	Reddish brown clay	1.3 m
1.	Sand and gravel	

The main difference from Davidson's section was the recognition of an erosion surface formed during the deposition of the upper yellowish-grey sediments. In a neighbouring borehole (Figure 15.2) clayey gravels were encountered within beds 3 and 4. These were considered to be due to slumping from a mound of submerged glaciofluvial sand and gravel (Paterson *et al*., 1981) or deposited from an iceberg (Armstrong *et al*., 1985). The change in colour during the period of deposition of the clays was thought to relate to the retreat of the ice sheet towards the west: the reddish clays at the base reflected derivation from local Old Red Sandstone, whereas the upper yellowish clays received their colour from material principally derived from Highland rock types.

The fauna described by Davidson (1932; Graham and Gregory, 1981) came principally from beds 3 and 4. The molluscan fauna consisted of the gastropods *Buccinum groenlandicum* (Chemnitz) and *Lunatia* pallida? (Broderip and Sowerby) and the bivalves *Astarte borealis* (Schumacher), *Hiatella arctica* (L.), *Macoma calcarea* (Chemnitz) , *Musculus laevigatus* (Gray),

Musculus niger (Gray), *Palliolum groenlandicum* (Sowerby) (=Arctinula greenlandica), *Portlandia arctica* (Gray), and *Thraciacf.septentrionalis* (Jeffreys). Although some of these species have wide geographical ranges, others, such as*Portlandia arctica* and *Palliolum groenlandicum* are strongly indicative of high-arctic conditions. Certain of the ostracods recovered are similarly indicative, for example,*Krithe glacialis* (Brady, Crosskey and Robertson), *Rabimilis mirabilis* (Brady) and *Cytheropteron montrosiense* (Brady, Crosskey and Robertson). Other macrofossils recovered include bones of the common seal,*Phoca vitulina* L.

The re-investigation of the site allowed a correlation to be established between the stratigraphy and the microfaunal distribution. The lowest marine deposits (bed 2) are characterized by the above-mentioned ostracods and in the foraminiferal assemblage,*Elphidium* clavatum (Cushman) predominates over *Elphidium* bartletti (Cushman). In bed 3, *Elphidium* bartletti attains dominance and there is a marked reduction in the occurrence of the ostracods Rabimilis mirabilis and *Cytheropteron arcuatum* (Brady, Crosskey and Robertson). Krithe glacilis disappears in bed 4, and *Elphidium* clavatum regains dominance in the foraminiferal assemblage. Bed 5 was barren of both micro- and macrofauna. Paterson *et al*. (1981) have suggested that it is not part of the Errol beds but should be correlated with the Powgavie Clays, a later deposit lacking the high-arctic indicator species: these clays were intersected in boreholes in the Carse of Gowrie to the east of Errol.

The variation in the microfauna appears mainly to reflect variations in salinity, bed 3 with the dominance of *Elphidium* bartletti being indicative of more fully marine conditions than either beds 2 or 4. The reduced salinity of bed 2 may be due to meltwater influx from the retreating ice sheet, whereas bed 4 may have been deposited in shallower water as sea level fell consequent upon isostatic uplift.

At the Gallowflat clay pit (surface altitude about 25 m), deposits similar to those at Inchcoonans are revealed. McManus (1972) described the sedimentary characteristics of the deposits, noting that they comprised laminated silty clay with thin sand layers. The lower part of the succession shows rhythmic bedding in silty clays or clayey silts, whereas the upper part comprises fine and medium sands. Pebbles and boulders up to 1.3 m in size occur as dropstones in the succession, and calcareous concretions are also present (Duck, 1990). The erratic material includes dolerite, metamorphic rocks and Old Red Sandstone sediments, sometimes striated (MacGregor, 1973; Duck, 1990) The only macrofossils recovered were *Portlandia* spp., and the microfauna consisted of the ostracod*Cythere montrosiense* (Brady, Crosskey and Robertson) and the foraminifera*Elphidium* clavatum and *Cassidulina obtusa* (Williamson), E. clavatum being dominant (Paterson *et al*., 1981).

Interpretation

By analogy with modern polar environments, McManus (1972) considered that the Errol beds were deposited in association with seasonal pack ice and icebergs in water depths of up to 100 m. Analysis of the calcareous concretions led Duck (1990) to support McManus's suggestion that the clays were deposited from flocculated suspensions in a strongly stratified water body and in the absence of significant currents. As the water shallowed and became more mixed, sedimentation of coarser particles occurred.

The earliest of the Errol beds were deposited when relative sea level was at least 28 m O.D in this area. During the subsequent fall in sea level particularly pronounced terraces were formed at 24–25 m O.D., and these have been correlated with the Main Perth Shoreline (Cullingford, 1972, 1977). This shoreline was formed when ice lay some distance to the west of the present area (see Almondbank) and, it has been argued (Paterson *et al*., 1981), at approximately the time of cessation of deposition of the Errol beds and the start of deposition of the Powgavie Clays with their fauna indicative of a milder climate. The shoreline has been traced widely along the coasts of east-central Scotland (Sissons *et al*., 1966; Smith *et al*., 1969) and has a marked tilt to the SE of 0.43 m/km resulting from isostatic uplift subsequent to the formation of the shoreline. The lower terraces in the Inchcoonans and Gallowflat area have been correlated with shorelines formed as sea level continued to fall. These terraces have successively lower tilts reflecting the decrease in isostatic uplift during the period of their formation (Cullingford, 1972, 1977).

The Errol beds have not been dated directly. Their base is clearly diachronous as they were laid down in front of a retreating ice sheet. On the basis of shoreline gradient calculations (Andrews and Dugdale, 1970) the start of deposition of the Errol beds can be placed at as early as 17,000 BP (Sutherland, 1984a) and, if deposition ceased at the time of change from arctic to more boreal conditions as the oceanic polar front retreated north of the Scottish coast (Ruddiman and McIntyre, 1973, 1981b; Peacock, 1981b, 1989b), then this may be placed at approximately 13,500 to 13,000 BP.

The Errol beds are an important element in the Late Devensian stratigraphy of Scotland. They are typified by a high-arctic fauna and their wide distribution along the east coast of Scotland indicates that the majority of the last ice sheet had melted prior to the climate amelioration at the opening of the Lateglacial Interstadial at around 13,000 BP. They are the equivalents, now on land, of the St Abbs Formation of the North Sea basin (Stoker *et al*., 1985). There are apparently few deposits on the west coast that may be correlated with the Errol beds, with two exceptions possibly at Stranraer (Brady *et al*., 1874) and in the North Minch (Gregory, 1980; Graham *et al*., 1990), and their absence from much of the west coast has been attributed to these areas being covered by ice during the period of their deposition (for example, Sissons, 1965; Peacock, 1975c). This hypothesis, however, awaits full substantiation (Sutherland, 1984a). Inchcoonans and Gallowflat constitute the principal reference area for the Errol beds, where the most abundant macro- and microfauna has been recovered and where the deposits have been examined in most detail in recent years.

The former pit at Inchcoonans which yielded the most abundant faunas is now infilled, but the deposits can still be examined in sections at Gallowflat clay pit.

Conclusions

Inchcoonans and Gallowflat are reference localities for a sequence of fossiliferous estuarine deposits (Errol beds) restricted almost entirely to eastern Scotland and formed during the melting of the last ice sheet (about 17,000–13,000 years ago). These sediments and the fossil fauna (marine mollusc shells) they contain, provide important evidence for marine environmental conditions during the early part of the Lateglacial. In particular, they indicate that the estuarine waters were high-arctic in character.

Reference list

Anderson, J.G.C. (1948) The fauna of the ?100 feet beach' clays. *Transactions of the Edinburgh Geological Society*, **14**, 220–9.

Andrews, J.T. and Dugdale, R.E. (1970) Age prediction of glacio-isostatic strandlines based on their gradients. *Geological Society of America Bulletin*, **81**, 3769–71.

Armstrong, M., Paterson, I.B. and Browne, M.A.E. (1985) *Geology of the Perth and Dundee district*. 1:50,000 geological sheets 48W, 48E, 49. Memoirs of the British Geological Survey (Scotland). London, HMSO, 108pp.

Brady, G.S., Crosskey, H.W. and Robertson, D. (1874) *A Monograph of the Post-Tertiary Entomostraca of Scotland*. London, Palaeontographical Society Monograph, 229 pp.

Brown, T. (1867) On the arctic shell clay of Elie and Errol, viewed in connection with our other glacial and more recent deposits. *Transactions of the Royal Society of Edinburgh*, **24**, 617–33.

Cullingford, R.A. (1972) Lateglacial and postglacial shoreline displacement in the Earn–Tay Area and Eastern Fife. Unpublished PhD thesis, University of Edinburgh.

Cullingford, R.A. (1977) Lateglacial raised shorelines and deglaciation in the Earn–Tay area. In *Studies in the Scottish Lateglacial Environment* (ed. J.M. Gray and J.J. Lowe). Oxford, Pergamon Press, 15–32.

Davidson, C.F. (1932) The arctic clay of Errol, Perthshire. *Transactions of the Perth Society for Natural Science*, **9**, 55–68.

Duck, R.W. (1990) S.E.M. study of clastic fabrics preserved in calcareous concretions from the late-Devensian Errol Beds, Tayside. *Scottish Journal of Geology*, **26**, 33–9.

Graham, D.K. and Gregory, D.M. (1981) A revision of C.F. Davidson's arctic fauna from Inchcoonans Claypit, Errol, held by the Museum and Art Gallery, Perth. *Scottish Journal of Geology*, **17**, 215–22.

Graham, D.K., Harland, R., Gregory, D.M., Long, D. and Morton A.C. (1990) The biostratigraphy and chronostratigraphy of BGS Borehole 78/4, North Minch. *Scottish Journal of Geology*, **26** 65–75.

Gregory, D. (1980) Assemblages of the ostracod *Cytheropteron montrosiense* Brady, Crosskey and Robertson from offshore Devensian deposits in the Minch, west of Scotland. *Scottish Journal of Geology*, **16**, 281–7.

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.

MacGregor, A.R. (1973) *Fife and Angus Geology. An Excursion Guide*. Edinburgh, Scottish Academic Press, 281pp.

McManus, J. (1972) Estuarine development and sediment distribution, with particular reference to the Tay. *Proceedings of the Royal Society of Edinburgh*, **71**, 97–113.

Paterson, I.B., Armstrong, M. and Browne, M.A.E. (1981) Quaternary estuarine deposits in the Tay-Earn area, Scotland. *Report of the Institute of Geological Sciences*, No. **81**/**7**, 35pp.

Peacock, J.D. (1975c) Scottish late and post-glacial marine deposits. In *Quaternary Studies in North East Scotland* (ed. A.M.D. Gemmell). Aberdeen, Department of Geography, University of Aberdeen, 45–8.

Peacock, J.D. (1981b) Scottish Late-glacial marine deposits and their environmental significance. In *The Quaternary in Britain* (eds J. Neale and J. Flenley). Oxford, Pergamon Press, 222–36.

Peacock, J.D. (1989b) Marine molluscs and Late Quaternary environmental studies with particular reference to the Late-glacial period in north-west Europe: a review. *Quaternary Science Reviews*, **8**, 179–92.

Robertson, D. (1875) Notes on the recent ostracoda and foraminifera of the Firth of Clyde, with some remarks on the distribution of mollusca. *Transactions of the Geological Society of Glasgow*, **5**, 112–53.

Ruddiman, W.F. and McIntyre, A. (1973) Time-transgressive deglacial retreat of polar waters from the North Atlantic. *Quaternary Research*, **3**, 117–30.

Ruddiman, W.F. and McIntyre, A. (1981b) The North Atlantic during the last deglaciation. *Palaeogeography*, *Palaeoclimatology*, *Palaeoecology*, **35**, 145–214.

Sissons, J.B. (1965) Quaternary. In *The Geology of Scotland* (ed. G.Y. Craig). Edinburgh, Oliver and Boyd, 467–503.

Sissons, J.B., Smith, D.E. and Cullingford, R.A. (1966) Late-glacial and post-glacial shorelines in south-east Scotland. *Transactions of the Institute of British Geographers*, **39**, 9–18.

Smith, D.E., Sissons, J.B. and Cullingford, R.A. (1969) Isobases for the Main Perth raised shoreline in south-east Scotland as determined by trend surface analysis. *Transactions of the Institute of British Geographers*, **46**, 45–52.

Stoker, M.S., Long, D. and Fyfe, J.A. (1985) A revised Quaternary stratigraphy for the central North Sea. *British Geological Survey Report*, **17**(2), 35pp.

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