ARDERSIER

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OS Grid Reference: NH780562

Highlights

The interest at Ardersier comprises ice-contact deposits of glaciomarine origin and a sequence of Lateglacial and Holocene raised shorelines. These features provide important evidence for interpreting the pattern of wastage of the Late Devensian ice-sheet, including a possible readvance, and the changes in relative sea level that both accompanied and followed the period of ice-melting.

Introduction

The site (NH 780562) is located on the Ardersier peninsula on the east coast of the Moray Firth, between Inverness and Nairn. It forms part of a suite of glaciomarine ice-contact deposits and raised shorelines and includes an area of high ground consisting of contorted silts, sands and clays, trimmed on the north and west sides by a series of Lateglacial and Holocene raised shorelines. These features provide significant evidence for interpreting both the pattern of ice-sheet deglaciation during the Late Devensian and subsequent changes in relative sea level. The landforms and deposits at Ardersier have been described by Jamieson (1874), Wallace (1883), Ogilvie (1914), Horne (1923), J.S. Smith (1968, 1977), Small and Smith (1971), Synge (1977b), Synge and Smith (1980) and Firth (1984, 1989b, 1990b) and have featured in most reconstructions of the Pleistocene history of the area. They have been interpreted as demonstrating a major readvance of the Late Devensian ice-sheet ('Ardersier Readvance') (J.S. Smith, 1968, 1977; Synge, 1977b; Synge and Smith, 1980), although this interpretation has recently been challenged (Firth, 1984, 1989b).

Description

The deposits at Ardersier (Figure 7.9) were first described by Jamieson (1874), who recorded, near Kirkton, a small exposure (NH 793561) of grey clay containing shells of arctic molluscs, which was either overlain by, or incorporated within a brownish deposit of gravel and silt. Wallace (1883) later reported further details of the shelly deposit and noted that specimens examined by Jamieson included *Nuculana pernula* (Müller), *Macoma calcarea* (Gmelin) and *Tridonta elliptica* (Brown). Robertson (in Wallace, 1883) identified *Astarte sulcata* (da Costa) and several species of ostracod and Foraminifera. An updated and corrected faunal list by D. K. Graham is presented in Firth (1990b). Although the shells were largely fragmented, Robertson noted that many of the pieces were in a natural position. Horne (1923) subsequently provided additional information on the stratigraphy of the Kirkton section:

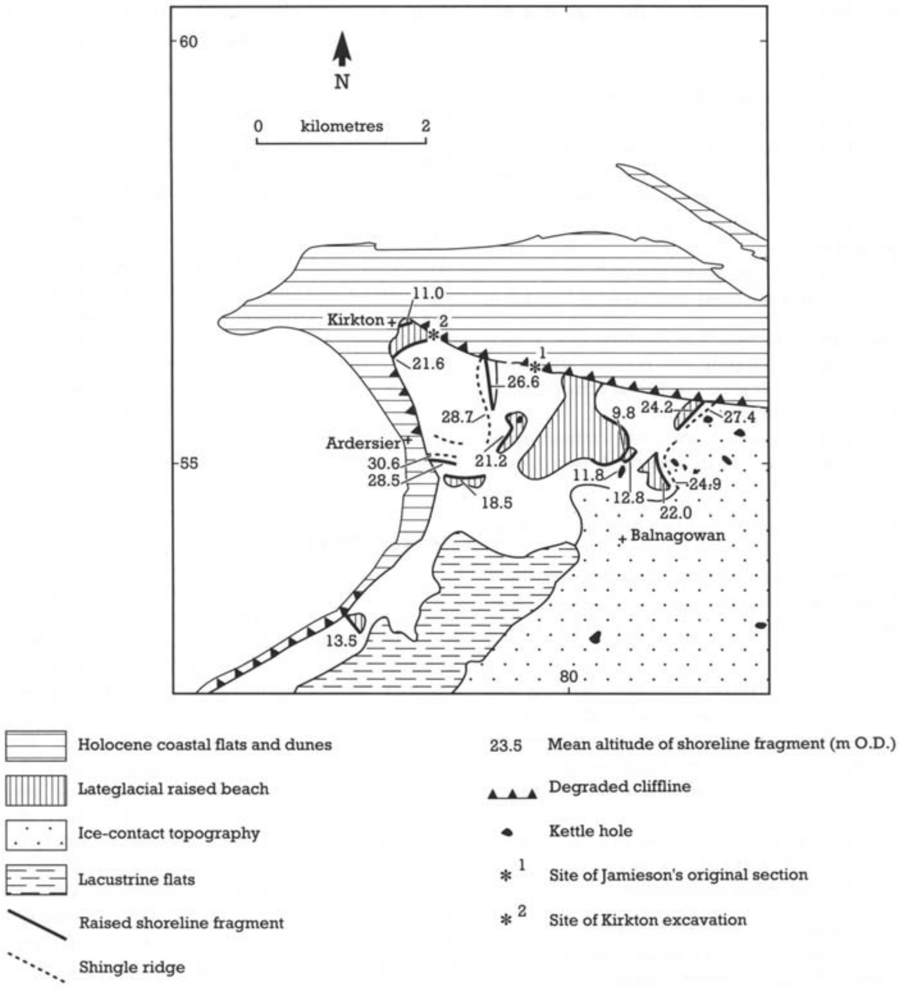

Figure 7.9: Geomorphology of the Ardersier area (from Firth, 1989b).

3.	Sand and clay deposit with some stones	1.2 m
2.	Stratified sand	1.8 m
1.	Grey, shelly clay	–

J.S. Smith (1968, 1977) referred to additional sections in the bluff behind theArdersier village, which "revealed beds of sand and silt which were folded, faulted and thrust, with inliers of blue clays' (Smith, 1977, p. 74).

Firth (1984, 1989b) described the following sequence in the bluff (NH 783565) east of Kirkton, but not, as he records, at the site of Jamieson's original section:

3. Horizontally bedded sands with well-rounded clasts

2. Finely laminated sands interbedded with massively bedded silts.

1. Massively bedded, grey clay.

This section was re-exposed in September 1990. The uppermost bed of pebbly sand was not exposed, but the remainder of the sequence was as follows:

4.	Obscured	4 m
3.	Thinly interbedded clay, very fine sand and silt occurring as graded couplets stacked into discrete units, possibly varves	1.5 m
2.	Thinly interbedded and interlaminated clay, silty clay and very fine sand; graded bedding	5 m
1.	Silty clay, medium grey, mainly massive but with some graded beds	1.9 m

Although the sequence was conformable, it was seen to be gently dipping and possibly glaciotectonized to a small degree. No faunal remains were recovered from the deposits.

In sections exposed in the fossil cliffline north of Ardersier village, Firth recorded two formations:

2. Undeformed sands and fine gravels (Hillhead Beds)

1. Deformed and/or tilted, massive silts interbedded with layers of clay, laminated fine-grained sands and lenses of gravel (Ardersier Silts)

The Ardersier Silts show convolute bedding and disturbance by load casts and water escape structures. Palaeocurrent directions are towards the north-east. Recent re-examination of the section at Hillhead has revealed a stack of thrust slices.

Re-excavation of the original section of Jamieson (1874), east of Kirkton, in September 1991 revealed the following succession:

3.	Sandy diamicton, including mainly finely stratified, but irregular shaped masses of massive stony diamicton; clasts up to 0.5 m size; laminated sand, silt and clay at base above planar contact with bed 2	2.0 m
2.	Sand, comprising a stack of thrust-bound slices (0.2–0.4 m thick), intercalated with thin (<0.15 m), sheared silty clay seams	3.2 m
1.	Sand, poorly bedded, with steeply dipping 3.4 m thrusts lined by sheared silty clay and folded seams of silty clay <0.2 m thick.	3.4 m

No shells were recovered in any of the beds.

The deposits at Ardersier rise to an altitude of about 40 m OD. They were trimmed by the sea during the Lateglacial and Holocene, producing a series of raised shorelines on the north and west side of the peninsula and an extensive relict cliffline (Ogilvie, 1914, 1923; J.S. Smith, 1968, 1977; Synge, 1977b; Synge and Smith, 1980; Firth, 1989b, 1990b). The highest marine features are well-developed Lateglacial shingle ridges at 28–31 m OD (Figure 7.9). Below, Lateglacial shoreline fragments occur at altitudes of 28.5 m, 26.6 m, 21–21.6 m, 18.5 m and 11 m OD (Figure 7.9). Later Holocene changes in relative sea level (see Firth and Haggart, 1989) are demonstrated by the raised beach deposits in front of the relict cliffline. These include the prominent shingle ridges noted by Synge and Smith (1980) near Kirkton, which are associated with the development of the distinctive coastal foreland and spit (Ogilvie, 1914).

Interpretation

Jamieson believed that the marine clay was the remnant of a more extensive deposit which had been destroyed during a later glacier advance. J.S. Smith (1968, 1977) interpreted the deposits, together with complementary features on the north side of the Moray Firth at

Fortrose, as a readvance moraine of the last ice-sheet. The shelly, marine clay was translocated from the floor of the firth during the readvance and glaciotectonically deformed with the other deposits to produce the high ground at Ardersier. As supporting evidence for an ice readvance, Smith (1977) also adduced a significant drop in the marine limit west of Ardersier. The concept of a readvance at Ardersier was later reaffirmed by Synge (1977b) and Synge and Smith (1980); these authors recognized it as the first of a series of retreat stages or readvances in their model of deglaciation of the inner Moray Firth and its hinterland.

Synge (1977b) and Synge and Smith (1980) integrated the Ardersier evidence into a general model of Lateglacial shoreline changes and ice-sheet retreat stages in the Moray Firth and Loch Ness areas. Briefly, deglaciation of the area was accompanied by high relative sea level at about 38–42 m OD as the ice retreated from near Nairn to Inverness. Subsequently the ice readvanced to Ardersier, and deglaciation was interrupted by further halt stages (see Chapter 6, Introduction). As ice recession continued west and south-west from Inverness, shorelines formed at 28–34 m, represented at Ardersier by a raised shingle ridge at 28–31 m and raised beach terraces at 28 m OD (Synge and Smith, 1980). Relative sea level continued to fall to a low position and then rose again, extending westwards along Strath Conon where deltas formed at Balblair and Contin at 26 m OD, and into Loch Ness where a clear shoreline developed; at Ardersier a prominent shoreline formed at 24 m OD. Sea level then fell before the Holocene transgression, and its associated shoreline development, which is represented by the raised beach terrace and cliffline at 8–9 m OD at Ardersier and the fine raised spits on which Kirkton stands.

Aspects of this model have been seriously questioned by Firth (1984, 1986, 1989a, 1989b) (see also Dores, Fort Augustus and Torvean) who presented a detailed reconstruction of relative sea-level changes and ice limits based on instrumental levelling of shorelines combined with geomorphological mapping. From the sedimentary and shoreline evidence both at Ardersier and over the wider area, Firth (1984, 1989b) concluded that the Ardersier Readvance could not be substantiated. He interpreted the Ardersier Silts, which extend up to an altitude of 37.8 m OD, as characteristic of subaqueous outwash deposition (*cf.* Anderson *et al.*, 1983; Eyles *et al.*, 1983; Eyles *et al.*, 1985; Powell, 1983; Benn and Dawson, 1987), and probably glaciomarine in view of the marine fauna at Kirkton. The Hillhead Beds, which extend up to about 40 m OD, were probably deposited in a high-energy marine environment. Firth considered that the deformation structures in the Ardersier Silts were not indicative of a major ice advance, but probably reflected loading, slumping or minor ice-front movement. It was also significant that major thrust structures and lodgement till, typical of large-scale glaciotectonics (*cf.* Moran, 1971; Banham, 1975), were apparently absent. Furthermore, analysis of the shoreline data showed no significant drop in the marine limit at Ardersier. The highest in the sequence of ten Lateglacial shorelines identified by Firth includes the highest shingle ridges at Ardersier (30.6 m OD) and is associated with an ice limit near Inverness. The glaciomarine sediments at Ardersier indicate relatively higher sea level when they were deposited at an ice margin at Ardersier, so that sea level dropped from at least 37.8 m to about 30 m OD while the ice retreated from Ardersier to Inverness. However, there is no evidence that this occurred while the active ice front was at Ardersier, as required by the model of Synge (1977b) and Synge and Smith (1980). In contrast, Firth's reconstructed shoreline sequence demonstrated a progressive fall in sea level as the ice-sheet retreated westwards (Firth, 1984, 1989a). Since the shorelines are truncated by the Main Lateglacial Shoreline in the area (Sissons, 1981c; Firth, 1984), which is believed to have formed during the Loch Lomond Stadial (Sissons, 1974d, 1981c), they must have been formed sometime before about 11,000 BP (Firth, 1989a).

The folds and thrust planes in the Ardersier Silts and in the sands at Kirkton, together with the presence of the diamicton at the top of the succession, originally described by Jamieson (1874) and confirmed in the recent excavation, have a significant bearing on the question of ice readvance. The diamicton may be interpreted either as a subaerial mass-flow or glaciomarine deposit, but in either case appears to require the close proximity of ice following glaciotectonism of the underlying finer-grained sediments. A readvance of the ice front is clearly indicated, although the shoreline evidence presented by Firth (1989b) appears to preclude an event of the magnitude suggested by Smith and Synge (J.S.Smith, 1968, 1977; Synge, 1977b; Synge and Smith, 1980).

The Quaternary geomorphology and sediments at Ardersier are important in several respects.

First, the juxtaposition of glacial and marine features is particularly significant; it has provided important evidence for interpreting the pattern of ice-sheet recession and relative sea-level change in the inner Moray Firth at the end of the last glaciation. As outlined above, two different reconstructions have been proposed. J.S. Smith (1968, 1977), Synge (1977b) and Synge and Smith (1980) believe that the deposits at Ardersier represent a readvance of the last ice-sheet. Elsewhere in eastern Scotland similar readvances are now largely discounted (Sissons, 1974c; Sutherland, 1984a), apart from the Elgin Oscillation (Peacock *et al*., 1968), although in north-west Scotland the Wester Ross Readvance is based on clear geomorphological evidence (Robinson and Ballantyne, 1979) (see Gairloch Moraine). The work of Firth (1984, 1989b), however, suggests a different interpretation for the Ardersier evidence, which does not require a major ice readvance but rather progressive ice recession. Ardersier is therefore one of a number of key sites in Scotland for interpreting the mode of deglaciation of the last ice-sheet.

Second, Ardersier is important for the sediments that comprise the core of the higher ground. These have a significant bearing on the interpretation of the mode of deglaciation and the contemporary sedimentary processes and environments. In the model of J.S. Smith (1968, 1977), Synge (1977b) and Synge and Smith (1980) these sediments represent ice-transported and deformed marine deposits; in the model of Firth (1984, 1989b), they represent a glaciomarine sequence deposited in front of a stationary ice margin. The Ardersier deposits therefore provide key evidence for reconstructing deglacial events in the inner Moray Firth and have significant potential for further sedimentological investigation, particularly at the original section described by Jamieson (1874) at Kirkton.

Third, Ardersier is notable for its shell-bearing deposits (Jamieson, 1874; Wallace, 1883). Although these have not been relocated, they nevertheless offer significant potential for establishing firm dating control on the deglaciation of the inner Moray Firth for the first time.

Fourth, Ardersier provides important morphological and stratigraphic evidence for relative sea-level changes during deglaciation. The Ardersier shorelines provide important datum points on the shoreline diagram constructed by Firth (1984, 1989a) for the Lateglacial Interstadial, complementing the evidence from Munlochy Valley and Barnyards. According to Firth (1984, 1989b) the deposits indicate that relative sea level attained an altitude of about 40 m OD at Ardersier and that it subsequently fell from at least 37.8 m to about 30 m OD as the ice retreated to Inverness. As the ice retreated farther west, the progressive fall in relative sea level continued.

Fifth, the assemblage of features at Ardersier is completed by Holocene raised beach deposits, including raised shingle ridges. Although these add to the diversity of interests of the site, the Holocene sequence in the area is better demonstrated at Barnyards and Munlochy Valley, and raised shingle ridges, both Lateglacial and Holocene, are most spectacularly developed at Tarbat Ness and Spey Bay (Ogilvie, 1923; Smith, 1977).

Conclusions

The landforms and deposits at Ardersier are important for interpreting the pattern of wastage of the last (Late Devensian) ice-sheet (about 14,000–13,000 years ago) and the changes in the relative position of sea level that accompanied and followed deglaciation. The deposits may represent a readvance of the last ice-sheet, although such an event and its magnitude are still a matter of debate. Beach deposits and shorelines show that relative sea level was as high as 40 m above present as the ice melted, and their presence has contributed towards understanding the wider regional patterns of sea-level changes during the Devensian (Lateglacial) and the Holocene (approximately the last 13,000 years).

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