Clava

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Highlights

The glacial deposits at Clava are famous for a shelly clay which has been interpreted either as an *in situ* marine deposit or a glacially transported raft of sediment. These deposits are Early or Middle Devensian in age. The site also has evidence for ice-sheet glaciation both older and younger than the shelly clay.

Introduction

The site at Clava [NH 766 442], located at an altitude of *c.* 150 m OD, 9 km east of Inverness, comprises a long-disused claypit and a series of sections along the lower Cassie Burn and the lower Finglack Burn, both tributaries of the River Nairn. The deposits, proved in the sections and in boreholes, form a complex glacigenic succession and include the famous, 'arctic' shelly clay. The latter was first described by Fraser (1882a, 1882b) in an old claypit excavated into a broad terrace feature (see Fraser, 1880). The shelly clay excited considerable controversy in the last century, concerning whether it was *in situ,* thereby representing a great submergence of the country during the Pleistocene, or whether it was transported by ice from offshore. This controversy was recently revived (Sutherland, 1981a), but subsequent detailed investigation by Merritt (1990b) has provided support for a glacially transported origin for the deposit. The site and its significance have been widely discussed in the literature, but the principal references are by Fraser (1882a, 1882b), Horne *et al.* (1894)*,* Sisson (1967a), Peacock (1975b), Holden (1977a), Sutherland (1981a) and Merritt (1990b, in press).

Description

Fraser (1882a, 1882b) noted shelly clay at the bottom of the claypit (now disused and overgrown), where it was overlain by fine, stratified sand, which was, in turn, overlain by boulder clay, soil and gravel. Chemical analysis of the shelly clay by W. I. Macadam showed it to be similar to clays derived from 'mixed gneiss and schist districts in the Highlands'. Although fragile, some of the shells were intact, with their periostraca preserved, and Fraser inferred that they occurred *in situ* in a former sea-bed deposit and at a similar altitude to the one supposed to exist at Chapelhall, near Airdrie (Smith, 1850a, 1850b). Fraser provided lists of mollusc shells, Foraminifera, ostracods and barnacles identified in the Clava deposits by T. F. Jamieson and D. Robertson, and considered that several species were diagnostic of arctic and shallow water marine conditions.

In view of the controversy over the Clava marine clay and its designated keystone role in the whole concept of glacial submergence (see below), a Committee of the British Association for the Advancement of Science was convened to carry out further investigations on the deposits. In the vicinity of the disused claypit (the 'Main Pit'), they excavated two pits and sank seven boreholes, which contributed greatly to the detailed knowledge of the site (Horne *et al.,* 1894). They established that the complete sequence of deposits was (Figure 7.8):

6.	Surface soil and sandy boulder clay	13.1 m
5.	Fine sand	6.1 m
4.	Shelly blue clay with stones in lower part	4.9 m
3.	Coarse gravel and sand	4.6 m
2.	Brown clay and stones	6.6 m
1.	Old Red Sandstone bedrock	—

Bed 4 was confirmed to be a marine deposit extending for at least 170 m and reaching a maximum thickness of 4.9 m. It was essentially horizontal and had well-defined contacts with the adjacent beds above and below. There was little sign of disturbance, although cracks and fissures were noted. Silt and clay were the main constituents, with a small number of clasts at the base. Of the latter, 59% comprised micaceous gneiss and 17% only of the local Old Red Sandstone. One piece of supposed Jurassic grit was found, the nearest source being *c.* 20 km to the north. Organic remains in the deposit were identified by D. Robertson, supplementing Fraser's original faunal list. They were shallow-water species representing an arctic or sub-arctic faunal assemblage. However, the variety of species was poorer than that recorded in the Lateglacial marine clays of the Clyde estuary or the east coast. The shells were not striated and were generally well-preserved with the periostraca intact, although some were partially crushed.

Compressed annelid burrows were also observed in the marine clay. Clasts in beds 3 and 6 were predominantly derived from the local bedrock, up to 76% in the case of the latter.

Subsequently the deposits were reinvestigated by Peacock (1975b). Although the original sections were no longer exposed, fresh ones had appeared along the Cassie Burn a few hundred metres to the south-west. Here, Peacock described three main sedimentary units. At the base was a till varying in composition from a stiff, silty till to almost stoneless soft sand and silt, and with marine shells, including Portlandia *arctica* (Gray), which had not previously been recorded at Clava. Above the till was a bed of poorly sorted sand and gravel, and on top a bed of silty till interbedded with discontinuous layers and streaks of finely laminated silt, sand and fine-grained gravel.

By interpolation, Peacock correlated these beds with beds 4, 5 and 6 respectively in the succession reported by Horne *et al.* (1894), although he did not relocate the Shelly clay of Horne *et al* (1894). Subsequently, from a detailed reinvestigation of the various sections along the Cassie Burn and the Finglack Burn, Merritt (1990b, in press) has proposed a composite succession. The full lithostratigraphy recognized by him and the provisional correlations with the successions of the British Association Committee (Horne *et al.,* 1894) are as follows:

	British Association bed numbers
12. Diamictic gravel	–
11. Finglack Till (flow-till facies)	–
10. Finglack Till (melt-out facies)	–
8. Finglack Till (resedimented)	–
7. Glaciofluvial Ice-contact Deposits	–
6. Clava Sand	5
5. Clava Shelly Clay	4
4. Clava Shelly Till	–
3. Drummore Gravel	3
2. Cassie Till	2
1. Bedrock	1

Merritt interpreted the Cassie Till (bed 2), known only from the British Association bore-holes, as a lodgement or basal melt-out till. The Drummore Gravel (Cassie Gravel of Merritt, 1990b) is exposed along the lower Finglack Burn, where it comprises principally a stratified, matrix-supported, gravelly, silty sand diamicton with a gravel composition of mainly sandstone and flagstone, with some metamorphic clasts; many of the gneiss and schist clasts are weathered. Merritt interpreted this unit as comprising subaerial sediment gravity flows that accumulated in an ice-marginal or supraglacial environment. From the relatively greater degree of weathering of this deposit, compared with the overlying bed, he inferred that it formed during an earlier glacial episode.

The Clava Shelly Till is exposed on the west side of the Cassie Burn and is described by Peacock (1975b) and Merritt (1990b). It comprises a stiff, matrix-supported diamicton with a matrix of silty, fine-sandy clay and contains clasts mainly of metamorphic rocks, but with some of granite and sandstone. Graham (1990) has confirmed the presence of *Portlandia arctica* in the deposit and listed a sparse microfossil assemblage. The presence of this bivalve provides evidence for a fully arctic environment (Peacock, 1975b; Graham, 1990) in contrast to the Clava Shelly Clay.

The Clava Shelly Clay is not presently exposed, and the main source of information has therefore been from the British Association investigation. Re-excavation of a temporary section at the site of the Main Pit, for a Quaternary Research Association field meeting in 1990, confirmed the principal findings, with particular attention drawn to the heavily sheared nature of the sediments. Graham (1990) has recently updated the taxonomic lists of the macrofauna and microfauna of the Shelly clay (Table 7.1). He noted the absence of exclusively arctic forms and concluded that the assemblage was indicative of a high-boreal or colder environment. Amino acid analysis of museum specimens of *Littorina littorea* (L.) yielded a mean ratio (D-alloisoleucine: L-isoleucine) of 0.04, suggesting that the shells may be Middle Devensian in age (D. Q. Bowen, unpublished data). Radiocarbon dating of a museum specimen of *Littorina littorea* also has yielded a Middle Devensian age (43,800 ± 3,300 BP, OxA–2483), but this date should be regarded as a minimum age, being so close to the limit of radiocarbon dating. Further radiocarbon dating of field specimens collected in 1990 has yielded infinite age estimates: *Astarte sulcata* (da Costa), >41,200 (OxA–2483) and *Littorina littorea,* >43,000 (OxA–2876) (*Merritt, in press*).

(Table 7.1) The macrofauna of the Clava Shelly Clay (from Graham, 1990)

Gastropoda

Boreotrophon clathratus (Strom)

Buccinum undatum Linné

Littorina littorea Linné

Littorina sp.

Littorina saxatilis (*Olivi*)*rudis* (Maton)

Lunatia pallida (Broderip and Sowerby)

Lunatia sp.

Margarites helicinus (Fabricius)

Margarites groenlandicus (Gmelin)

Neptunea antiqua (Linné)

Oenopota scalaris (Moeller)

Oenopota trevelliana (Turton)

Oenopota turricula nobilis (Moeller)

Oenopota turricula (Montagu)

Oenopota sp.

Omalogyra atomus (Philippi)

Rissoa parva? (da Costa)

Bivalvia

Astarte sulcata (da Costa)

Cerastoderma edule (*Linné*)

Lepton nitidum Turton

Macoma balthica (Linné)

Macoma calcarea (Gmelin)

Macoma sp.

Mytilus edulis (Linné)

Nicania montagui (Dillwyn)

Nucula sp.

Nuculoma tenuis (Montagu)

Nuculana pernula (Müller)

Nuculana sp.

Thyasira flexuosa (Montagu)*

Tridonta elliptica (Brown)

Tridonta sp.

Yoldiella lenticula s.l. (Müller)

Yoldiella sp.

bivalve indet.

mytilacean fragments

unidentifiable bivalve fragments

Cirripedia

Balanus balanoides Linné

Balanus crenatus? Bruguière

Balanus sp. plates

Decapoda

crustacean claw

* probably a misidentification of one of the colder water species *Thyasira gouldi* (Philippi) or *Thyasira sarsi* (Philippi).

The Clava Sand at the Main Pit shows poorly defined subhorizontal lamination and a well-developed system of clastic veins, which Merritt (1990b) has interpreted as the product of brittle fracture while the material was frozen and either overridden by, or transported within, glacial ice. Evidence of shearing of the deposit is also present near the junction with the overlying till. Clava Sand is also found overlying Clava Shelly Till in the Cassie Burn section (Merritt, 1990b), where it is folded as well as being cut by microfaults and shear planes. The Clava Shelly Till has been folded also.

The Glaciofluvial Ice-contact Deposits unit (bed 7), exposed on the west bank of the Cassie Burn, is a part waterlain and part mass-flow deposit, which is cut by a series of shear planes (Merritt, 1990b).

The Finglack Till is exposed in sections along the lower Finglack Burn and on the west side of the Cassie Burn (Peacock, 1975b; Merritt, 1990b). The clasts consist mainly of sandstone and flagstone, and the unit comprises a succession of lodgement, melt-out and flow-till facies. The origin of the overlying Diamictic gravel is uncertain (Merritt, 1990b).

Interpretation

In the period following its discovery, the significance of the Clava Shelly Clay was considered by both protagonists and antagonists of the glacial submergence theory of the time (cf. Davies, 1968a). Richardson (1882) referred to Clava as one of a number of high-level arctic shell beds in the British Isles indicating an extensive submergence during the glacial period. He also correlated these high-level deposits with shelly clays at many lower-level sites around the coast of Scotland.

Jamieson (1882b) thought the Clava deposit implied a similar amount of submergence to that which he inferred from the quartz and flint gravels at Windy Hills. Wilson (1886) associated the shelly clay at Clava with the so-called interglacial beds of Aberdeenshire (for example at Kippet Hills) and ascribed them to the same submergence. Crosskey (1887) re-examined the Clava shell-bed and supported Fraser's conclusion that it was a true *in situ* sea-bed deposit, citing its lack of disturbance and mixing with other debris, its sharp junction with the overlying sands and the preservation of the distinctive arctic shell assemblage.

Bell (1893a, 1893b, 1895a), however, argued that because of their limited extent and the lack of marine organisms in the overlying deposits, both the Clava and Chapelhall shell beds had been transported to their present positions by land ice. He considered that if subsequent glaciation had removed all traces of high-level marine deposits except at a few localities, it was difficult to explain why there were no marine remains in the overlying till. Significantly, also, clasts in the marine clay at Clava were not derived from local Old Red Sandstone rocks. In the case of Clava, Bell suggested that ice issuing from the Great Glen was deflected eastwards by an ice barrier in the Moray Firth and that it crossed part of the sea floor before reaching Clava. He also argued that the high-level shelly deposits in North Wales, Ireland and at Chapel-hall did not provide substantive evidence for a 'great submergence' during the glacial period (Bell, 1891a, 1893b).

The majority of the British Association Committee concluded that the marine deposits were *in situ,* indicating former submergence of the land up to about 150 m OD. As evidence they cited the assemblage of organic remains, their mode of occurrence, the extent of the deposits and their apparently undisturbed character. A minority of the Committee (Bell and Kendall), however, argued that there was insufficient evidence to reach a firm conclusion and, moreover, doubted that there was any substantial evidence at all in Scotland for a great submergence. They questioned the widespread absence of shell beds and other traces of submergence and the lack of marine organisms in the overlying till. Although acknowledging certain difficulties, notably the extent of the deposit and the good preservation of the shells, they favoured an ice-rafted origin for the shelly clay, with a source area in Loch Ness, judging from ice-movement patterns inferred from striae and erratics.

In view of the lack of unanimity on the conclusions to the British Association Report, it was not surprising that debate on the origin and implications of the Clava shell bed continued. Indeed, Clava assumed even greater significance following the failure of a similar British Association Committee to relocate the shell bed at Chapelhall (Horne *et al.,* 1895). Further shell beds, however, were found in Kintyre (Horne *et al.,* 1897). In the years immediately following the British Association investigations, Bell (1896a, 1897a, 1897b) continued to argue against the Clava and other similar deposits being *in situ* and resulting from an extensive marine submergence. He received support from Lamplugh (1906). In contrast, Reade (1896), Smith (1896a) and Jamieson (1906) maintained the view that the deposits were the product of a major marine submergence.

In the Geological Survey Memoir for the area, Horne (1923) summarized the findings of the British Association Committee, but produced no new evidence. Later, Bremner (1934a) speculated that the Clava marine beds might be pre-glacial, since there was no boulder clay beneath them. Bourcart (1938), however, suggested a possible correlation of the Clava marine clays with the Tyrrhenian marine transgression (Mindel–Riss interglacial). Charlesworth (1956) also favoured the view that the deposits were *in situ,* representing an interglacial submergence.

In contrast, Sissons (1967a) considered that the Jurassic erratic, the low content of local rocks and the marine fossils themselves all suggested that the material had been ice-rafted from the north prior to the last ice movement, from southwest to north-east.

Despite the inconclusiveness of the British Association Report and the significant implications for the Pleistocene history of Scotland if the deposits were *in situ,* there was no reinvestigation of the area until the work of Peacock (1975b). He argued that the shelly clay at Clava was part of a till unit comprising reworked sea-floor material. It was probably an autochthonous melt-out till (cf. Boulton, 1968) rather than a lodgement or flow till, since the preservation of annelid burrows precludes resedimentation. The existence of such intact erratics of marine sediments, often with well-preserved fossils and structures, has been widely documented (Jamieson *et al.,* 1898; Lamplugh, 1911; Debenham, 1919; Read, 1923; Eyles *et al.,* 1949; Peacock, 1966, 1971a), and possible mechanisms of entrainment have been proposed (Moran, 1971; Boul-ton, 1972a; Banham, 1975). Peacock related the characteristics of the sand and gravel bed (bed 5 in the succession of Horne *et al.,* 1894) along the Cassie Burn to deposition in a high-energy, fluvial environment and he explained the overlying beds (see above) as a succession of flow tills deposited in an environment similar to that of modern ice margins in Svalbard (Boulton, 1968).

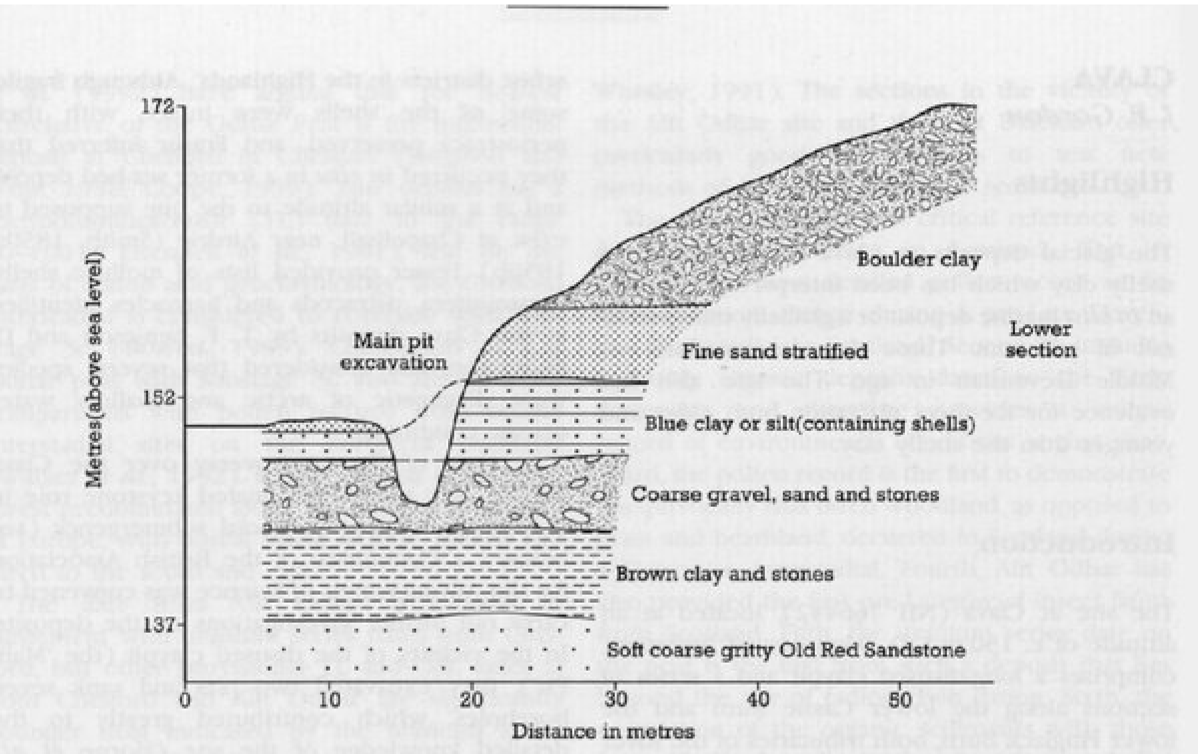
Holden (1977a) considered that the last ice movement in the area was from the Great Glen and that it was moving, therefore, in the wrong direction to transport sea-floor materials inland. He argued that the Clava Shelly Clay was similar in characteristics and location to those at Tangy Glen in Kintyre and at Afton Lodge in Ayrshire. From his investigation of the Afton Lodge deposits, and in view of the apparent problems entailed in the ice-rafting explanation at Clava and Kintyre, he concluded that all three were *in situ* and represented a pre-Devensian sea-level stand at between 115 m and 150 m OD. Sutherland (1981a) also accepted an *in situ* origin for the high-level shell beds and presented a model relating these deposits to glacio-isostatically induced submergence in front of an expanding ice-sheet. However, the deposits at Clava fit only partly into the overall distribution pattern of the high-level shell beds and are apparently at too great an altitude to be fully explained by the model.

More recently, the detailed work of Merritt (1990b) has provided a significant advance in resolving the origin of what has been one of the most enigmatic Pleistocene deposits in Scotland. He summarizes the evidence for and against the shelly clay being *in situ.* The arguments in support have included the good state of preservation of the shells, the large size of the bed and its near horizontal form; counter arguments have included the occurrence elsewhere of large ice-rafted deposits with well-preserved shell contents, the lack of other evidence of sea levels at a comparable altitude to the Clava deposits and the distinctive composition of the shelly clay compared with the overlying and underlying deposits. In considering the evidence, Merritt (1990b) noted similarities with large, glacially transported rafts or 'megablocks' in North America (Moran *et al.,* 1980; Aber, 1985, 1989), particularly concerning the presence of glaciotectonic deformations. He correlated the Clava Sand overlying the Clava Shelly Clay at the Main Pit with lithologically similar sand overlying the Clava Shelly Till in the Cassie Burn sections, the latter in turn overlain unconformably by the glaciofluvial sand and gravel unit described by Peacock (1975b). He interpreted the deformation structures in the shelly till and the overlying sands, not simply as the result of overriding by the ice that deposited the Finglack Till, but as structures that were already in place and therefore formed as part of the transport and emplacement processes of these deposits. Peacock (1975b) considered that shelly clay graded into the shelly till, in a similar manner to the rafts of marine clay in the till at Boyne Quarry, near Portsoy (see below); such a pattern would conform with glaciotectonic deformation of megablocks during transportation (cf. Aber, 1985). However, as the shelly till contains a fauna indicative of colder conditions than the main raft of shelly clay, the two formations are not simply derived one from the other; the till is formed from a part of the sequence not preserved at the Main Pit (Merritt, in press). The reconstructed pattern of ice movement suggested that the source of the shelly clay was the Loch Ness Basin, which was inferred to have been an arm of the sea prior to the ice advance. The process of rafting involved the development of high pore-water pressures within interbedded sands and clays within the semi-enclosed basin of Loch Ness. The results of amino acid analysis and radiocarbon dating indicate that the shelly clay is Middle or Early Devensian in age and that it was transported by the Late Devensian ice-sheet.

Conclusion

Clava is best known for a bed of shelly clay that has had a significant bearing on interpretations of the Pleistocene history of Scotland. Although it has been suggested that the deposit is an *in situ* marine clay and reflects a phase of high sea level, either before or at the time of the build-up of the last (Late Devensian) ice-sheet, current interpretations indicate that it was transported *en masse* to its present location by the last ice-sheet (approximately 18,000 years ago). Clava is not only a site of historical importance, but is also recognized to be significant for studies of glacial sedimentation.

References



(Figure 7.8) Clava: lithological succession at the 'Main Pit' (from Horne et al., 1894).