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Early Holocene relative sea-level changes at Clachan Harbour, Raasay, Scottish Hebrides

Archive Report No 1781

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Executive Summary

The focus of this study is the inter-tidal sediment and eroding woody peat exposed in Clachan Harbour, Isle of Raasay, in the Scottish Inner Hebrides. These deposits were investigated as part of a wider project to monitor the impact of a new harbour and infrastructure works. Previous surveys of the harbour recorded the extent of the eroding peat along with borehole investigations and diatom analysis. Further excavation work supported by a programme of radiocarbon dating has raised the significance of the site, particularly in the light of Mesolithic worked stone tools which were found at the head of the harbour. Important sea-level data has been attained through altitudinal levelling thus allowing the site to be placed in its local and regional context.

Introduction

This report presents the results of research into early Holocene relative sea-level changes in Clachan Harbour, Churchton Bay, Raasay (NGR: NG 54465 36404). The research was undertaken in 2007 in advance of the construction of a new ferry terminal and formed part of a wider study, including the excavation of a Mesolithic worked lithic assemblage (Ballin *et al.* forthcoming) and the assessment of the vulnerability of intertidal peat deposits within the bay (Cressey *et al.* 2007). The work was commissioned and funded by The Highland Council.

Clachan Harbour is a sheltered crescent-shaped embayment that lies to the south of Raasay House, facing the Narrows of Raasay and overlooking the Isle of Skye (Figure 1). The area has a mesoscale tidal regime and, therefore, gravel terraces and shingle ridges are widespread around the coast. The first study of quiet water and organic sedimentation patterns on Raasay was conducted as part of the *Scotland's First Settlement Project* in 2000 (Dawson 2009) and extensive wood and peat deposits, from which two worked lithics were recovered (Hardy and Wickham-Jones 2002), were discovered covering the western part of the bay (Figure 1). The work in 2000 provided the first evidence for morphological and stratigraphical evidence for sea-level changes (ibid). The research undertaken in 2007 was designed to enhance the earlier work by providing a robust radiocarbon chronology for the sea-level changes.

Palaeoenvironmental background

Intertidal organic deposits including peat and wood are vulnerable to erosion, due to their dynamic locations. Such deposits are a rare and valuable repository of palaeoenvironmental information, which can be used to provide dating material to establish the timing of relative sea level change in Scotland. Published investigations include those for the intertidal reaches of the River Tay (Cullingford *et al.* 1980; Cressey & Dawson 2010) and eroding intertidal peats within the Solway Firth (Cressey *et al.* 2001). Recent investigations closer to the Isle of Raasay include projects on Islay and Coll (Dawson *et al.* 1998; Dawson *et al.* 2001); the Isle of Skye (Selby *et al.* 2000; Selby 2004; Selby and Smith 2007); and in the vicinity of Arisaig (Shennan *et al.* 1995; 2005).

The Isle of Skye, to the west of Raasay, provides the closest analogy for Holocene relative sea level changes on Raasay. Raised shorelines formed during or following the culmination of the Main Postglacial Transgression are widespread in Skye and reach up to 7m OD in eastern Skye at Sconser, the Braes and Peinchorran (Benn 1991). In more exposed locations the raised shingle ridges occur at higher altitudes (up to 10m OD). The nearest site to Raasay is a raised tombolo of vegetated beach gravels at c.7m OD at the Braes (Selby and Smith 2007), on Skye opposite Churchton Bay.

A comprehensive survey of isolation basins, available organic coastal accumulations and back-barrier peat accumulations (Selby *et al.* 2000; Selby and Smith 2007) has provided information concerning late Devensian and Holocene sea levels throughout

Skye. Closest to Raasay is Peinchorran, a peat moss located between two relict tombolos composed of sand and gravel (Selby and Smith 2007). The ridges are located at c.7–8m OD and evidence for two lagoonal phases, determined from diatom and pollen analyses, has been recorded. The two lagoonal phases attain c.6m OD and 6.2m OD in altitude and date to c.7900–6600 and after c.4200 BP respectively. This evidence provides data on quiet water sedimentation evidence for marine inundation to at least 5m OD.

Fieldwork Methods

All boreholes and monolith locations were levelled to Ordnance Datum (OD) Newlyn. Tidal data was taken from Portree, Skye and levels related in the discussion to High Water Mark of Ordinary Spring Tides (HWMOST) refer to the position in the tidal cycle that the transition from estuarine to terrestrial sedimentation occurs.

Site investigation involved hand-coring from north to south across the harbour sub-surface (Figure 1) to determine the spatial extent of the buried peats and wood remains. It was established that the peat is mainly concentrated within the central northern part of the bay (Figure 1). It is probable that the peat survives extensively under the storm beach.

Two areas of the inter-tidal peat (Areas F1 and F2 on Figure 1) were explored, due to their higher potential for erosion. Lithics were recovered from both areas (Ballin *et al.* forthcoming). A full register of contexts can be found in the archive report (Cressey *et* *al.* 2007). Only those that are necessary to describe the stratification are used in this report; they are the four digit numbers in brackets.

Area F1 was a strip of upstanding peat and tree root remains, c.13.5m long by 4m wide at its southern end and 0.6m at its northern end (Figure 2). Recent peat cutting was visible as vertical cut marks on the east and west sides. Two trenches were excavated in Area F1. Trench 1 was 4.25m long by 0.5m wide, and aligned north to south. Modern-day marine shingle of shingle was removed to expose the surface of the compact amorphous woody peat (1110), which was c.0.3m deep at maximum and became shallower towards the north end of the section (Figure 3). Beneath the peat, a band of humic silt was present which was seen to continue much deeper during the earlier borehole investigations.

Area F2 was initially identified as a thin, fragmentary strip of peat jutting out to the south of the cobble storm beach. A trench measuring 3m by 3m was excavated over this area (Figure 1). Two detailed section drawings of the deposits were produced: one east-facing (Figure 4) and one south-facing (Figure 5). Excavation revealed that the storm beach cobbles (2101) overlay shell-rich sand (2102) which in turn overlay peat (2104). The peat lay on natural orange silty clay (2106) and bedrock. Thin lenses of dark brown to black compacted silt (2105) were present between the peat (2104) and the natural orange silty clay (2106) mainly in the centre and on the eastern side of the area (Figure 4).

Sampling procedure

Monolith Tin 1 was taken from the northern end of Area F1 (Fig 3) for diatom analysis by Sue Dawson in 2000 (Dawson 2009). The biostratigraphic profile recorded in this tin is shown alongside the diatom percentage diagram (Figure 3). Two samples of wood were obtained from the interface between the humic silt layer (1101) and (1100).

Monolith Tin 2 was taken from the east-facing section of Trench 1 in Area F1 (Figure 3). The tin was dominated by woody peat (1100) with black humic silt layer at its base (1101). The woody peat (1100) exhibits a variable thickness across the area, being up to 0.25m thick in places. The humic silt (1101) extends to greater depths in excess of several metres (according to the borehole data)

Monolith Tin 3 was taken from the south-facing section of Area F2 (Figure 5). The tin encompassed the stratigraphic zones 2101, 2102, 2103, 2104 and 2105. Worked lithics were recovered from the lower deposits (2104 and 2105; Figure 6; Ballin *et al.* forthcoming).

Microfossil analyses

Sediment was sub-sampled from the monolith tins. Microfossil analyses of the sub-samples followed standard laboratory preparation techniques and included preparation for both diatoms and pollen. A minimum of 300 microfossils was counted at every level sampled. Eighteen levels were prepared for diatoms using standard techniques (Barber and Haworth 1981).

Diatoms were identified with reference to Hendey (1964) and Van der Werff and Huls (1957–74). Diatom nomenclature follows Hartley (1986) and salinity and lifeform classification is based on Vos and de Wolf (1993) and Denys (1992). In general polyhalobian and mesohalobian classes broadly reflect marine and brackish conditions and oligohalobian and halophilics reflect more freshwater environments. The diatom diagram is presented as a percentage diatom diagram and the results are summarized below to place the radiocarbon dated material in context.

Radiocarbon dates

Ten samples were assayed for radiocarbon determinations (Table 1). Two individual samples from a given context were submitted for assay to ensure within sample integrity. The uncalibrated dates are shown in Figure 7. The dates range between 9500 and 8230 uncal BP.

No	Lab code	Trench	Context No.	Species type	Age uncal. BP
1	GU-15995	Area F1 Monolith 2	1101/1100 boundary	Betula wood	9510 ± 35
2	GU-15996	Area F1 Monolith 2	1101/1100 boundary	Betula wood	9230 ± 35
3	GU-16001	Area F1, Monolith 2	1100	Wood undif	8710 ± 35
4	GU-16002	Area F1, Monolith 2	1100	Wood undif	8375 ± 40
5	GU-15997	Area F2 Monolith 1	1110	Betula wood	9525 ± 35
6	GU-15998	Area F2 Monolith 1	1100	Betula wood	8885 ± 35
7	GU-15999	Area F2, Monolith 3	2104	Wood undif	9315 ± 40
8	GU-16000	Area F2, Monolith 3	2104	Betula wood	9510 ± 35
9	GU-17165	Area F2 Monolith 3	2104	Betula wood	8545 ± 30
10	GU-17166	Area F2 Monolith 3	2104	Betula wood	8230 ± 30

Table 1 Radiocarbon dates. The number in the first column references the sample locations shown on Figs. 3 and 5.

Biostratigraphical results of the diatom analysis (Figure 8)

The diatom assemblage for Clachan Harbour exhibits, at the base of the sequence, the clastic sediments composed of silts and sands have increasing numbers of Mesohalobous (brackish) diatom taxa. High frequencies of *Diploneis interrupta* and *Navicula peregrina* are indicative of saltings in the supratidal zone. Low numbers of marine and marine-brackish species, including *Diploneis didyma*, *Achnanthes delicatula* and *Navicula digito-radiata* occur in the sands suggesting deposition on mud or sandflats (Vos and de Wolf 1993). As the contact with the overlying organic sediments is approached, the diatom assemblage returns to Mesohalobous dominated, with *Diploneis interrupta* and *Diploneis ovalis* prominent. The organic unit is characterized by increasing values of oligohalobian (Freshwater) species, with *Fragilaria* sp. and *Navicula pusilla* in greatest numbers. This assemblage is characteristic of a reduction in marine influence. The silty sands providing a thin veneer over the organic sediments across the harbour floor surface are characterized by polyhalobous and mesohalobous species including *Paralia sulcata*, Cocconeis scutellum, *Navicula peregrina*, *Nitzschia punctata* and *Diploneis didyma*. The presence of these brackish species together with the aeophile *Diploneis interrupta* indicates deposition within the inter-tidal area. Two radiocarbon AMS dates on *Betula* fragments were obtained from the organic unit. The first sample from the base of the organic sediments directly overlying the humic sandy silts gave a date of 9510±35 BP. A second date towards to top of the organic unit gave 9315±40 shows that these deposits become progressively become younger towards the surface.

Pollen analyses undertaken on the same samples as the diatoms are published in full elsewhere (Green and Edwards 2009). The base of the organic deposits is characterized by tree pollen including *Betula* with low counts of *Pinus* and *Salix* and high frequencies of Cyperaceae, low *Artemisia* and minimal counts of *Rumex*. Sedge, willow and birch continue to rise throughout the organic unit. Rising values for *Corylus avellana*-type occur towards the top of the organic deposit and suggest a continued presence of hazel scrub in the vicinity of the site. The continuous rise for *Betula* plus the commencement and development of *Corylus avellana*-type at Clachan Harbour suggest that birch–hazel woodland was established in the area and conform to the early Holocene, c.9300 BP, date for the expansion of woodland of this type throughout the Hebrides proposed by Birks (1989).

Relative sea-level changes in Raasay and North-West Scotland (Figure 9)

Analysis and dating of the intertidal organic units across Churchton Bay has allowed the pattern of relative sea level changes to be determined in Raasay during the early Holocene. The complex changes determined are a result of the interplay between glacio-isostatic processes which, at times, outpaced the amount of rise provided by the global sea surface changes. The rate of rebound is variable across the Inner Hebrides from the mainland due to the variability of the ice thickness across the area.

The uppermost date on the organic peat layer suggests a rise in sea level after c.8200 BP. The stratigraphic evidence for this transgression is present in the thin veneer of sediments overlying the organic unit across the harbour, although much erosion of the sand unit has undoubtedly taken place due to its situation within the present day intertidal zone. The raised shorelines around the harbour provide morphological expression of this transgression with shingle ridges located at c.7.5m OD and c.9m OD. It is likely that the uppermost shoreline expression may date to c.4000–3000 BP, analogous to the sediments in Skye studied by Selby *et al.* (2000; 2007).

Woodland development: inception and inundation

Intertidal woody peat in south-west Raasay began to accumulate during the early Holocene around c.9500 BP at which time relative sea level fell close to 0m OD or slightly lower. Birch woodland continued to develop at the site and probably was in existence for c.1200 years. Terrestrial organic sedimentation and the development of woodland accumulated at, or close to, sea level until some time after c.8200 BP. After this date, the woodland was inundated and subsequently submerged by a rise in sea level which reached an altitude of at least c.7.6m OD, the highest Holocene terrace immediately north-east of the inter-tidal zone in the grounds of Raasay House.

Clachan Harbour in a regional context

In recent years relative sea-level data has been obtained from a variety of coastal settings around the Isle of Skye. Furthermore, data from the mainland of Scotland (Arisaig) and islands of Coll and Islay allows the Raasay evidence to be placed in a wider chronological and spatial context.

Analysis by Selby *et al.* (2000; 2007) for relative sea-level changes in south-western and eastern Skye provides equivocal evidence for the inception of the Main

Postglacial Transgression in the early Holocene. An isolation basin at Inver Aulavaig (south-west Skye) dates freshwater conditions at c.8800 BP and marine by c.7600 BP. Data from Peinchorran in eastern Skye, opposite Raasay, has brackish lagoonal phases at c.7900 and c.4200–3900 BP. This is in broad agreement with the Raasay data. The transgression maximum may have culminated here as recently as c.3000 BP.

The sediments analysed from the floor of the harbour in south-west Raasay, together with the information from the raised shingle terraces surrounding the harbour area, have been used to determine the pattern of relative sea-level changes for Raasay during the Holocene. A graph of relative sea-level change for the Inner Hebrides (Figure 9) has been drawn using data from the Isle of Coll (Dawson *et al.* 2001) and the recent data from Isle of Raasay. The earliest part of the Holocene was characterized by low relative sea-levels at c.0m OD or slightly lower. The contact between the silts and clays and the overlying intertidal organic unit at 0.15m OD marks a change from marine sedimentation, typical of an intertidal environment, to terrestrial sedimentation above the influence of marine activity. This boundary marks a relative marine regression in Clachan Harbour in the earliest part of the Holocene. Relative sea-level remained low, sufficiently long enough to allow the growth of woodland, although it was probably at these levels for between 500 and 1000 years. There then ensued a rise in relative sea-level which commenced at c.8800 radiocarbon years BP on the Isle of Skye (Selby *et al.* 2000). Pollen evidence from Clachan Harbour suggests that the transgression may be earlier than the Skye and Coll data and be closer to the timing of the transgression on the Isle of Islay around c.9500 radiocarbon years BP (Dawson *et al.* 1998). The raised shorelines around Clachan

Harbour provide morphological expression of this transgression with shingle ridges located at c.7.5m OD and c.9m OD. The stratigraphic evidence for this transgression is present in the thin veneer (2103) overlying the organic unit across the bay, although much erosion of the sand unit has undoubtedly taken place due to its situation within the present day intertidal zone. The ridges at c.7m OD are comparable to terraces located around the Isle of Skye and mark the culmination of the Main Postglacial Shoreline.

The stratigraphic position and altitude of the inter-tidal sediments is consistent with the results of relative sea-level investigations undertaken on sediments of a similar age in Islay (Gruinart flats) and north-east Coll (2001). Relative sea level data for this transgression from Kentra Moss (Loch Shiel) and Arisaig, Moidart (Shennan *et al.* 1995; 2005) are in agreement with the Clachan Harbour data. At Arisaig, marine influence in isolation basins exists until c.4000 BP and are at higher altitudes due to the variability in the uplift history between the two areas (Shennan *et al.* 1995).

Conclusion

Organic sediments across the harbour floor at Clachan Harbour, Raasay have allowed models to be proposed for early Holocene relative sea level changes and intertidal organic spatial and temporal change. Biostratigraphical and radiocarbon analyses have provided a robust chronology and environment of deposition which concur in dating the onset of organic sedimentation and the cessation of marine conditions at the site after 9500 BP. Information of the rise of relative sea level in the early Holocene with the onset of the Main Postglacial Transgression suggest woodland conditions existed at the site for c.1200 years, and marine waters inundated the organic unit some time after 8230 BP. This accords with sites around the Inner Hebrides in Skye, Coll and Islay. Raised shorelines surrounding the harbour, in the vicinity of Raasay House, are likely to be a product of mid and late Holocene sea level.

The discovery of 27 worked stone tools (Ballin *et al.* forthcoming) in association with worked wood and charcoal at the head of the bay indicates Early Mesolithic activity within the embayment. This activity was carried out within a local landscape dominated by birch and hazel woodland.

The fieldwork has demonstrated that there are four zones of geomorphological activity within the harbour: accreting sand-flats; an eroding and accreting storm beach; a pebble and shingle beach; and an eroding low cliff at the mean high watermark (Figure 1). The bay is subject to annual monitoring work to assess the vulnerability of the intertidal deposits from recent dredging operations during harbour construction and from changes to the erosion patterns that may be caused by the presence of the new ferry terminal. Reports on that monitoring work will be lodged with the Royal Commission of Ancient and Historical Monuments of Scotland (RCAHMS) and with the Highland Council Archaeology Unit (HCAU).

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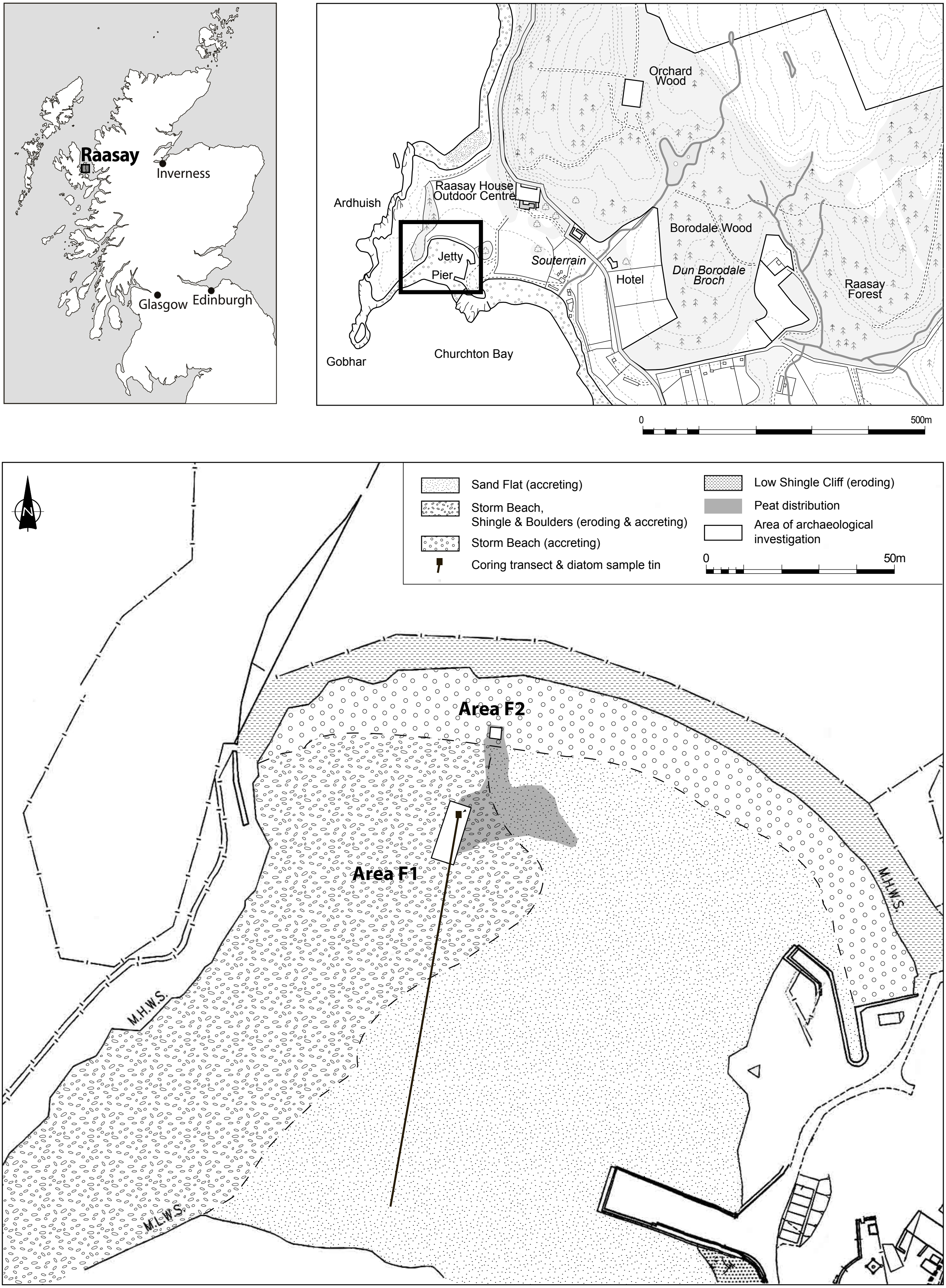

Fig. 1 - Location of Clachan Harbour, Raasay,
showing location of inter-tidal peat and areas investigated

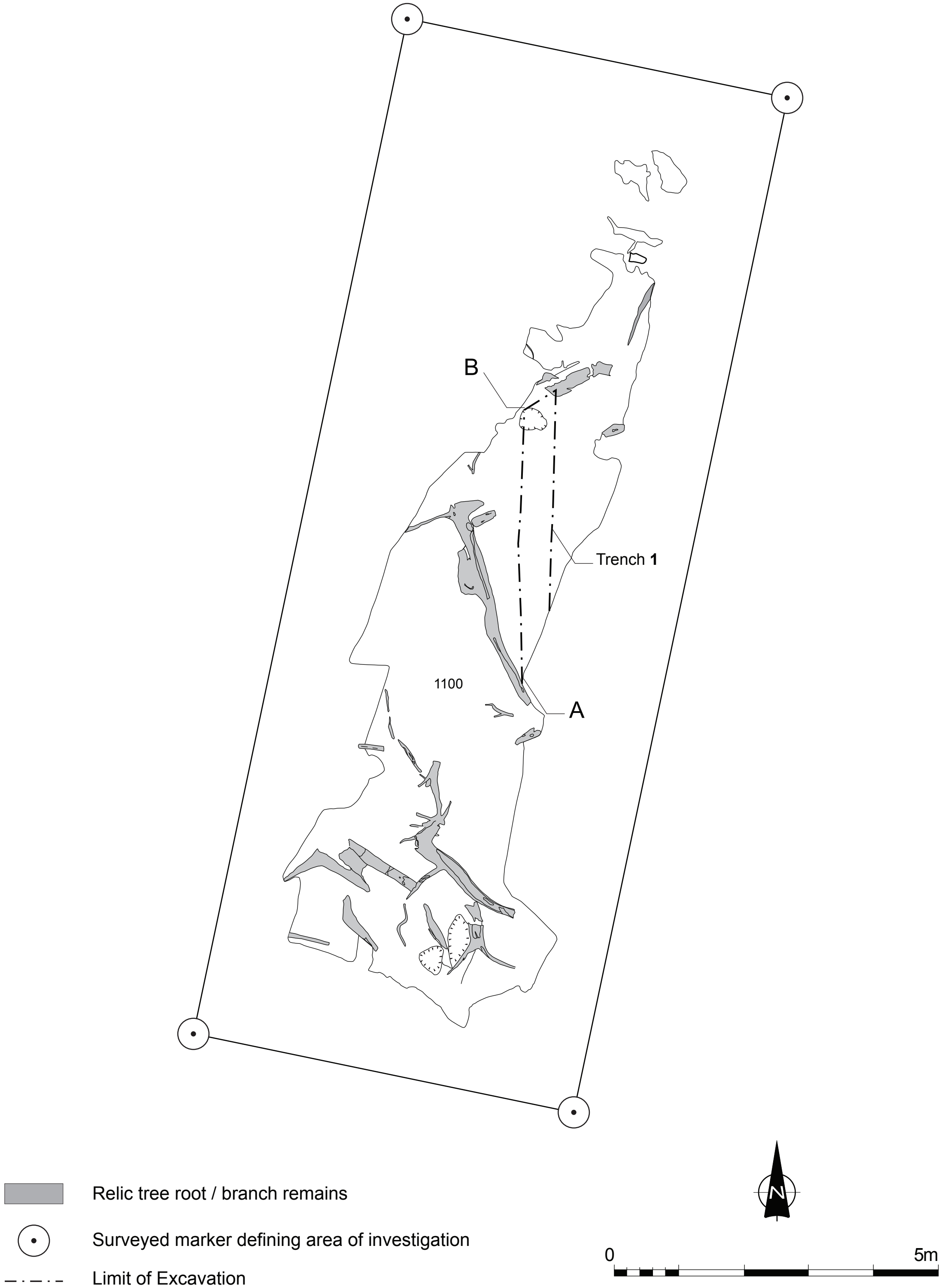

Fig. 2 - Post-excavation plan of Area F1.

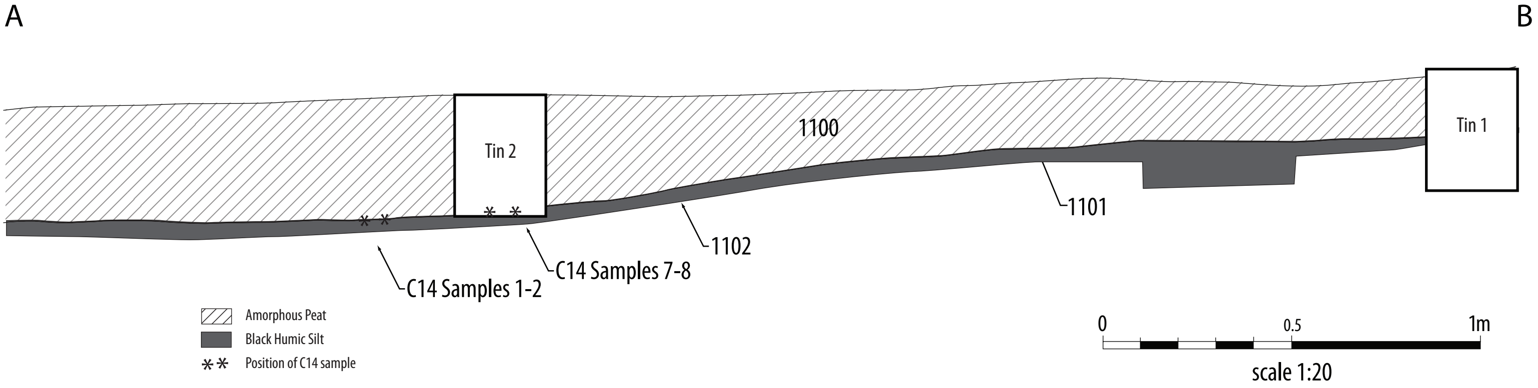

Fig. 3 - Trench 1, east-facing section showing biostratigraphy

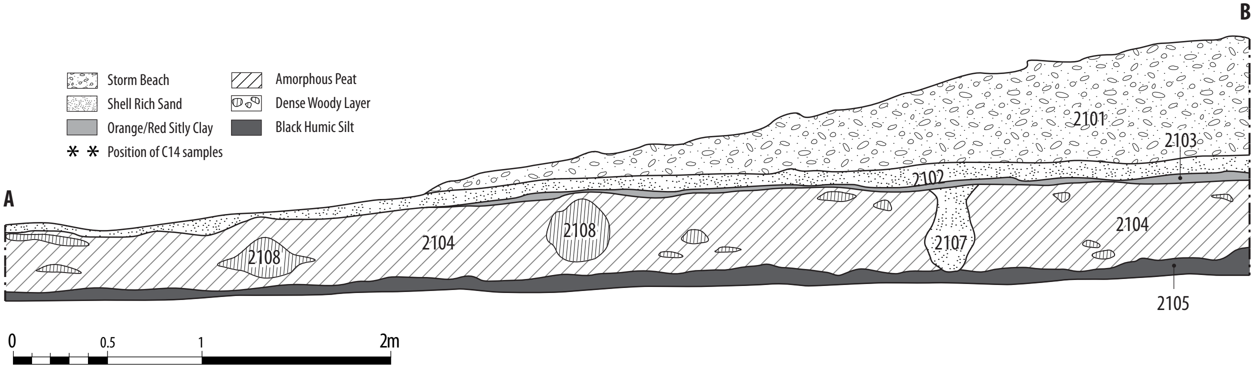

Fig. 4 - Area F2, east-facing section showing biostratigraphy

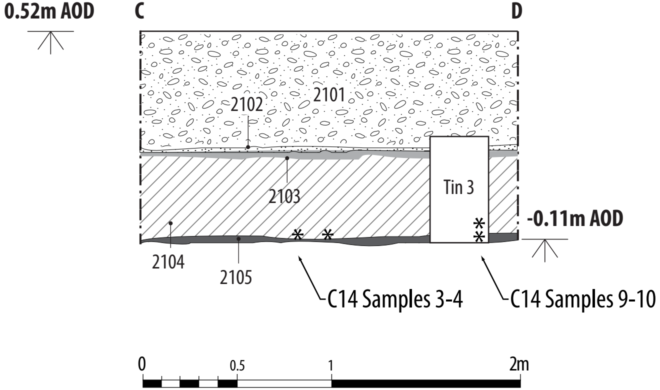

Fig. 5 - Area F2, south-facing section showing biostratigraphy

Fig. 6 - A Mesolithic stone tool found in situ sealed below woody peat in Trench 2, layer 2104

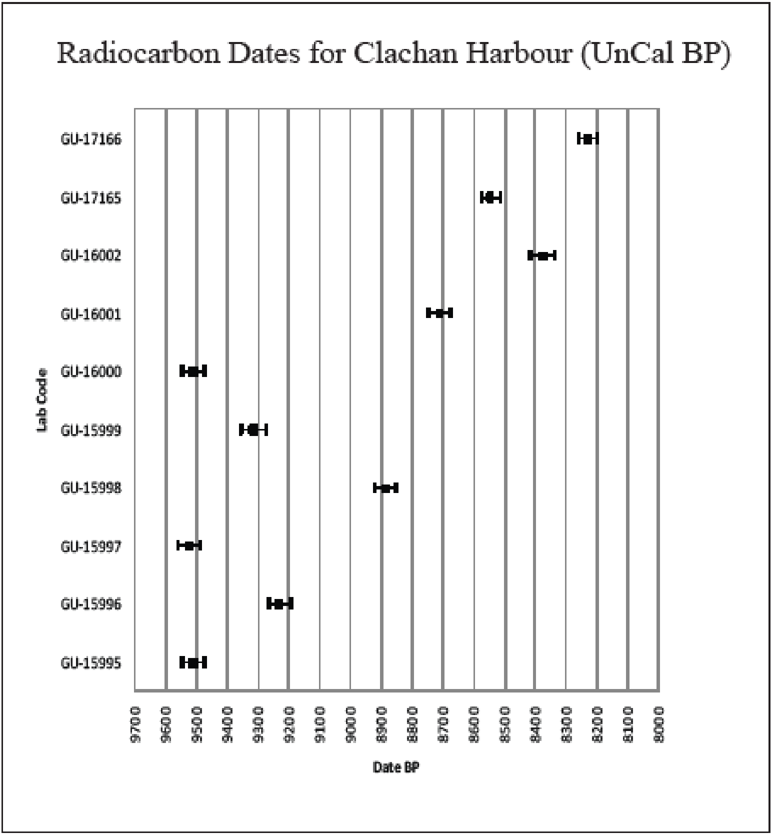

Fig. 7 - Churchton Bay radiocarbon dating determinations, with calibrations carried out by the lab using Oxcal 3 (Bronk Ramsay 2000) and the 1998 calibration curve (Stuiver et al 1998).

Raasay: Clachan Harbour Monolith 1
Altitude of surface : +0.17 m.O.D.

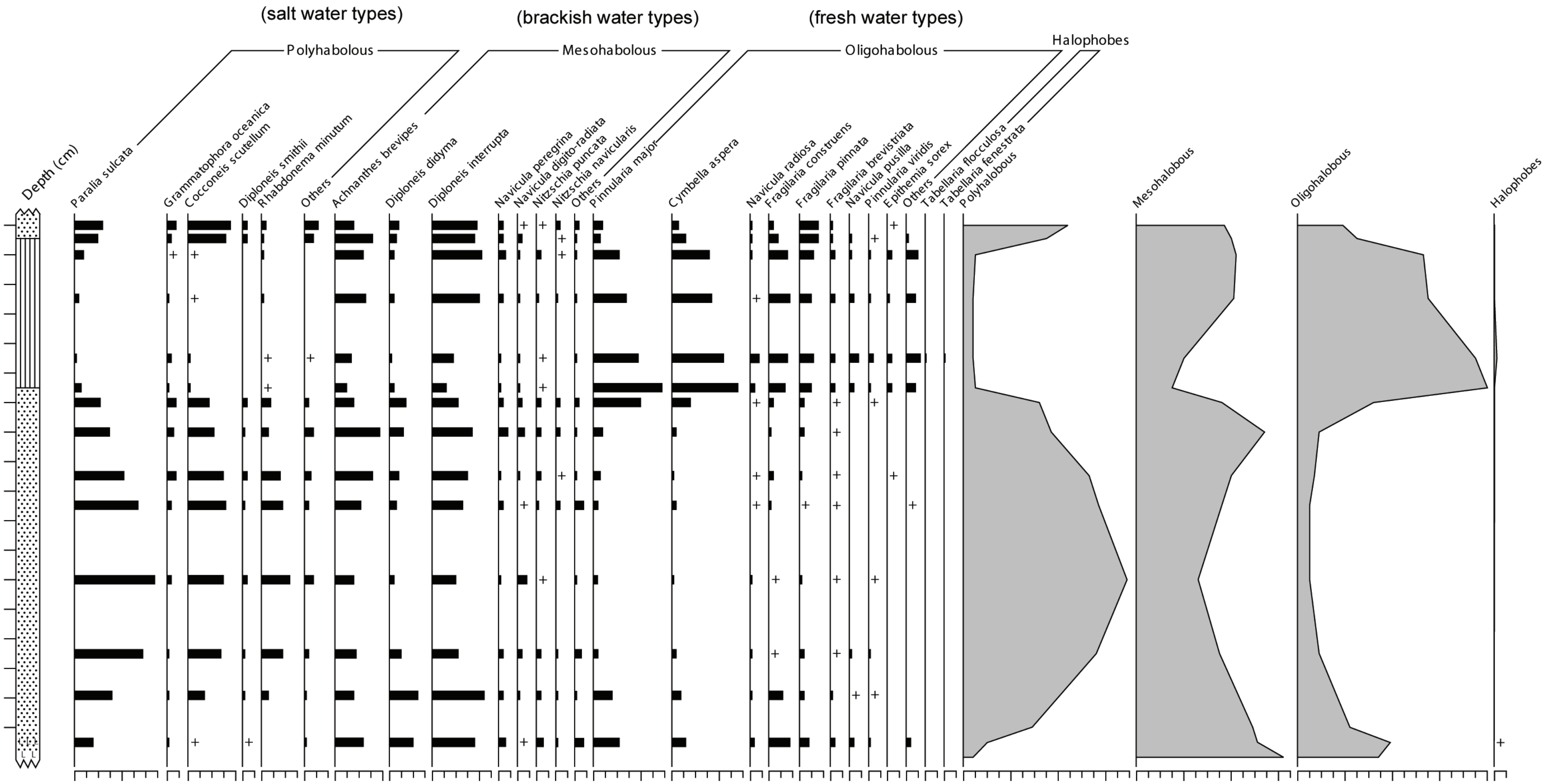

Figure 8. Percentage diatom diagram from Monolith 1.

Woody peat   Sand   + <0.5%

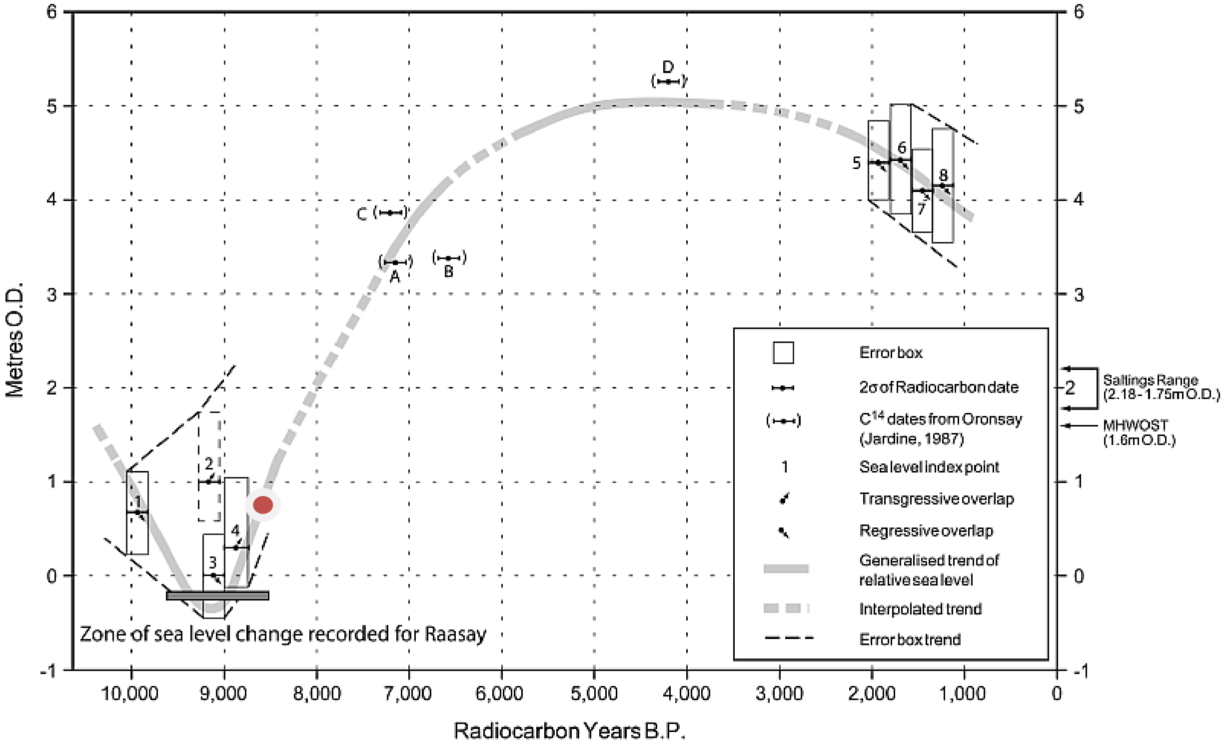

Fig. 9 - Relative sea level graph, Scottish Inner Hebrides (adapted from Dawson *et al* 1998).

● = average radiocarbon dates obtained from wood above the diatom sequence