3 (c) SUMMARY OF FLANDRIAN SEA-LEVEL CHANGES IN THE INNER MORAY FIRTH

1. Introduction

Little or no previous work has been published for the Moray Firth area explicitly dealing with sea-level change during the Flandrian Age. This is extremely surprising because it is now sixty years since Ogilvie (1923) stated that the area "contains some of the finest and most complex examples of raised beach at several levels" (p 377).

Ogilvie's impressive and detailed monograph is, however, primarily a morphological study concerned with the changing shape of the coast between Golspie and Port Gordon. It contains a fine description of the great variety of beach form encountered in the Moray Firth area including the high fault-controlled cliffs on the south-east coast of the Black Isle, the flat carselands of the Beauly Firth and the desolate (now afforested) sand and shingle foreland of the Culbin Sands. It is perhaps indicative of the quality of Ogilvie's work, coupled to the lack of research since that comparatively recent publications use his work extensively (Sissons 1967, 1976, Steers 1973). However the work contains little reference to stratigraphy and offers only the broadest time control.

Evidence for Flandrian sea-level change is often implicit in the published literature and there is no synthesis available. A brief summary of the disparate pieces of information follows.

At a number of sites around the shores of the Moray Firth thin layers of peat are found beneath later marine deposits or below present MHWS. Wallace (1883, 1896) records local memory of an extensive peat bed covering the floor of Burghead Bay; the rights of turbary were the subject of a law suit in 1787. The peat layer was formerly more extensive than the present sporadic occurrences, though at one site (0.6 m O.D.) c. 50 cm of compact woody peat was observed to overlie blue-grey silty sand containing abundant shell fragments.

Eyles et al (1946) provide information of a buried peat layer in the Spynie depression. A brick-clay pit, worked until 1939 near Loch Spynie, c. 5 km north of Elgin contained a peat layer 38 cm thick, 570 cm from the surface overlain by a shell bed and blown sand and underlain by c. 45 cm of light blue clay and over 600 cm of dark clay. Near to Beauly, on Barnyards Farm they also make reference to a trial pit excavated for brick clay where a thin peat layer, 0.3 m thick was noted to underlie 2.3 m of brown and grey clay. Further observations of peat layers underlying later marine deposits are recorded by Smith and Mather (1973) on the Morrich More, J. S. Smith (1968) at Delny and the Geological Survey near Lower Kincraig.

Some morphological forms have also been used as evidence for a lower sea-level, J. S. Smith (1963) calls attention to the well developed gullies between Cromarty and Jemimaville on the southern shore of the Cromarty Firth. The gullies are sharply incised into higher, earlier beach deposits and are graded to a level below that of the Flandrian raised beaches. There are no debris cones at or below the junction with the lower raised beach which would tend to indicate they are older forms. Smith (1963) favoured an early Atlantic age c. 5,000 B.P. Sissons et al

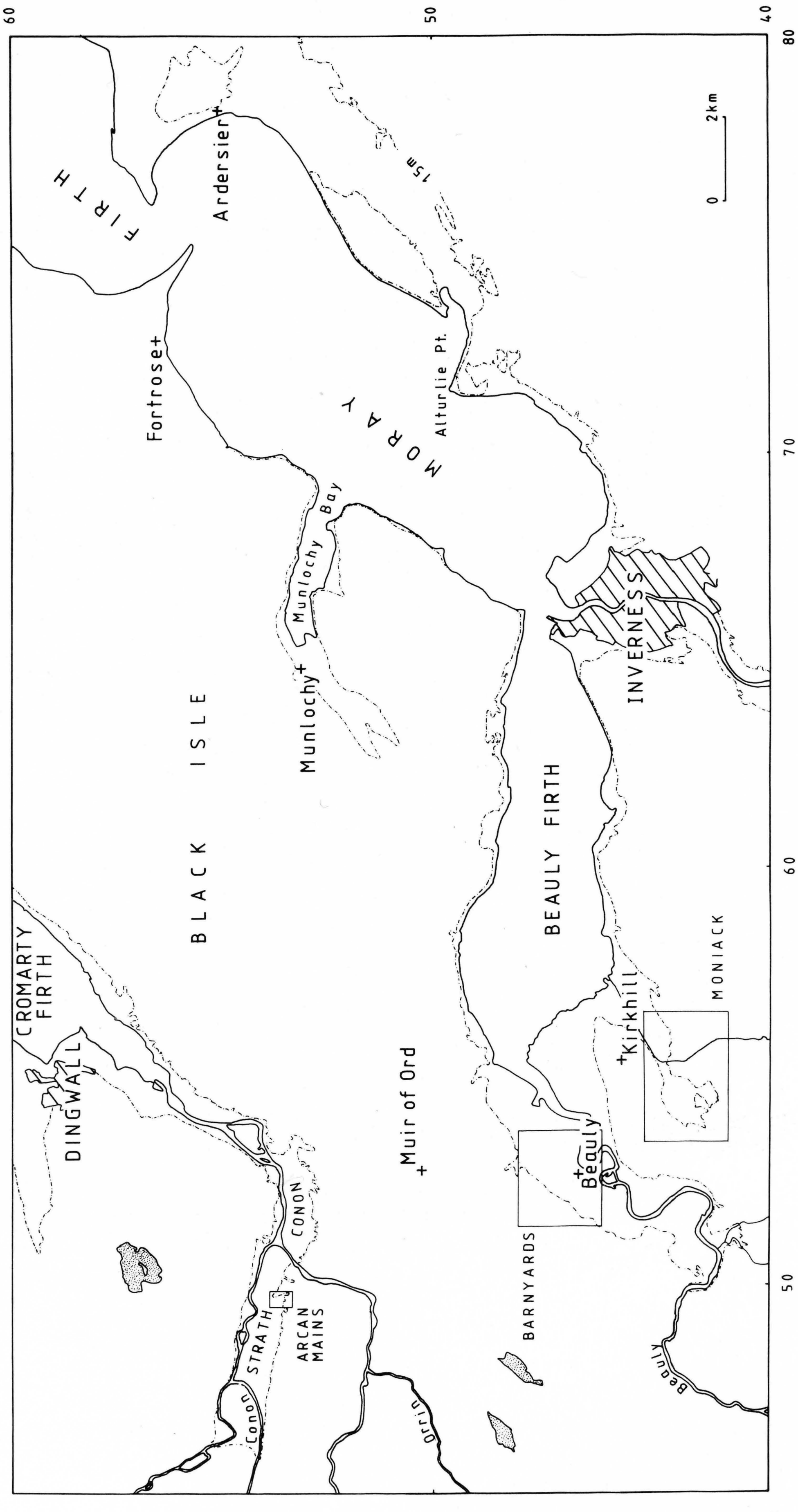
MORAY FIRTH
Ardersier
Fortrose
Alturlie Pt.
Munlochy Bay
Munlochy
BLACK ISLE
INVERNESS
BEAULY FIRTH
CROMARTY FIRTH
DINGWALL
Muir of Ord
Kirkhill
MONIACK
Beauly
BARNYARDS
CONON
STRATH
Conon
ARCAN MAINS
Orrin
Beauly
15m
0
2km
60
50
40
80
70
60
50

FIG. 1

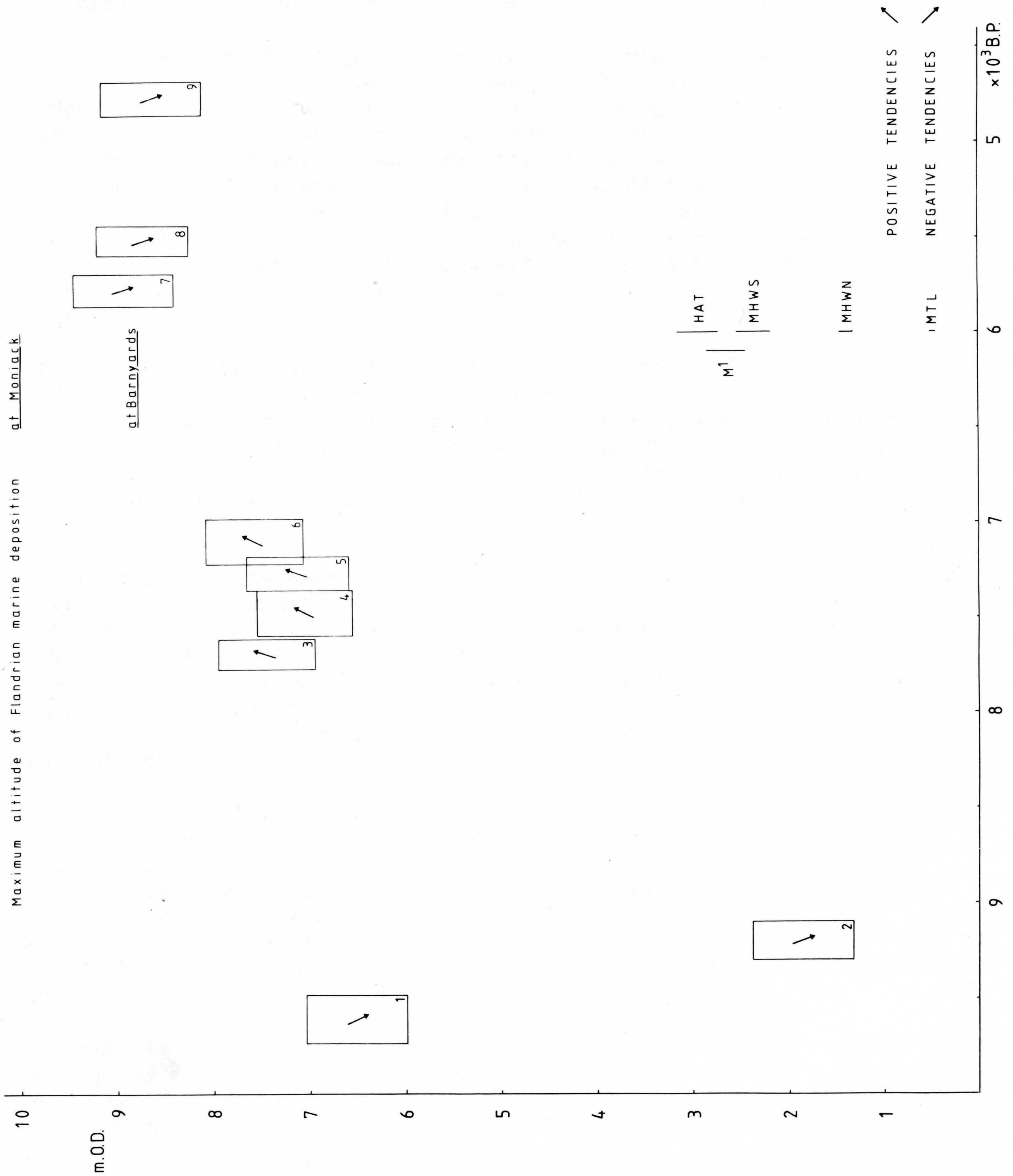
Maximum altitude of Flandrian marine deposition at Moniack
at Barnyards
HAT
MHWS
MHWN
MTL
M1
POSITIVE TENDENCIES
NEGATIVE TENDENCIES
m.O.D.
×10³ B.P.
1 2 3 4 5 6 7 8 9 10
5 6 7 8 9

FIG. 2

(1965) criticized the paper and described similar forms in the Forth and Tay area that are older and were in existence at least 8,000 to 8,500 BP.

The only detailed stratigraphic record with independent age corroboration pertaining to Flandrian sea-level change is that given by Peacock et al (1980) for the Cromarty Firth borehold C2. Using all borehole data three informal lithologic units have been described: from the base up, the Findon beds, Ardullie beds span the transition from Late Devensian to Flandrian. There are three radiocarbon dates from the lower Cromarty beds, SRR1068, 8748 ± 80 B.P. dating plant debris and two dates on shells, SRR1069 at 7326 ± 360 B.P. and SRR 1070 at 8156 ± 150 B.P. All dates have been normalized with respect to the P.D.B. standard. The lower Cromarty beds therefore probably accumulated during the early Flandrian.

If the marine shell dates are to be questioned then the lower Cromarty beds accumulated c. 8750 B.P. at the time of the relative low sea-level recorded in the Forth. The lower Cromarty beds have a high proportion of very shallow water species and the stratigraphy contains possible channel lag deposits. If the age quoted above is correct, an altitude of -6 m O.D. for the contemporary sea-level is reasonable (Peacock et al 1980).

If the plant debris date is to be questioned and shell dates accepted then the lower Cromarty beds accumulated between 8,000 B.P. and 6,500 B.P. at the time of the rise in sea-level to the Flandrian maximum in the Forth. The shallow water fauna could then be explained through downward translocation of shallow water and intertidal species. The fauna of the Upper Cromarty Beds indicate deposition in deeper water which may relate to the culmination of the Flandrian rise in sea-level and subsequent events.

Flandrian raised beaches have been described by the field officers of the Geological Survey (Horne and Hinxman 1914, Peach 1912, Read et al 1925, Read et al 1926) by Ogilvie (1923) and Steers (1937) though accurate height measurements and overall synthesis are lacking. Smith (1966) notes two Flandrian raised beaches, the higher one rises from 8.22 m at Kessock to 9.14 m at Tarradale, a gradient of c. 0.09 m/km. The lower beach is at 3.9 m O.D. but accurate height determination was impossible due to disturbance by road building.

In conclusion the fragmentary data suggest a relatively low sea-level during the early Flandrian - perhaps lower than -6 m O.D. at c. 8750 B.P. - followed by a rise to produce the well developed raised beach at c. 9-10 m O.D. in the inner firths and by intermittent fall to the present level.

2. A Flandrian Sea-Level 'Curve' for the Inner Moray Firth

Nine new radiocarbon dates from three sites at Barnyards (NH 5247), Moniack (NH 5443), and Arcan Mains (NH 4954) (Fig. 1) provide a preliminary time control for sea-level change during the early and mid-Flandrian. The approach used in 'curve' construction (Fig. 2) is essentially a site-based one and relies on lithostratigraphic and biostratigraphic evidence to argue for direction in sea-level movement with height determinations and radiocarbon dates allowing index points to be located with respect to the ordinates of age and altitude. The 'curve' is depicted as a series of error boxes and represents the approximate course of MHWS between c. 9600 and c. 5500 B.P. Details of stratigraphy, environmental evidence and interpretation in terms of sea-level movement are given in Haggart (1982).

The altitudinal error boxes include consideration of sampling error and the indicative range of each dated index point (after Shennan 1980). No attempt is made to correct for consolidation of sediments or changes in palaeotidal range. The age error box is representative of a range of 16 about the mean of each radiocarbon date. Further details are given in Table 1.

TABLE 1

Index Point	Altitude (m)	Mean Age B.P.	Site
1	5.98 - 7.03	9610	Barnyards
2	1.33 - 2.38	9200	Barnyards
3	6.93 - 7.94	7700	Arcan
4	6.52 - 7.53	7430	Moniack
5	6.57 - 7.62	7270	Moniack
6	7.05 - 8.06	7100	Moniack
7	8.15 - 9.20	5510	Barnyards
8	8.39 - 9.44	5575	Arcan
9	8.10 - 9.15	4760	Moniack

The course of MHWS is suggested to have fallen from between 5.98 - 7.03 m at 9610 B.P. to 1.33 - 2.38 m at 9200 B.P., both dates coming from the regressive overlap of the lower peat at Barnyards. Although the dates are not significantly different at the 95% level it is assumed an age difference of c. 400 years exists between these two points based on pollen data. This gives a maximum rate of fall of 3.17 m/100 yrs and a minimum rate of 0.56 m/100 yrs.

The minimum altitude of the early Flandrian fall in sea-level is not known but Peacock et al (1980) suggest a figure of -6 m O.D. based on marine faunal studies of the Cromarty C2 borehole. Their ^{14}C date from derived plant debris at 8748 ± 100 B.P. could give a broad estimate of the age for this minimum. Morphological evidence for an early Flandrian low sea-level includes the impressive incised gullies between Jemimaville and Cromarty, mentioned above.

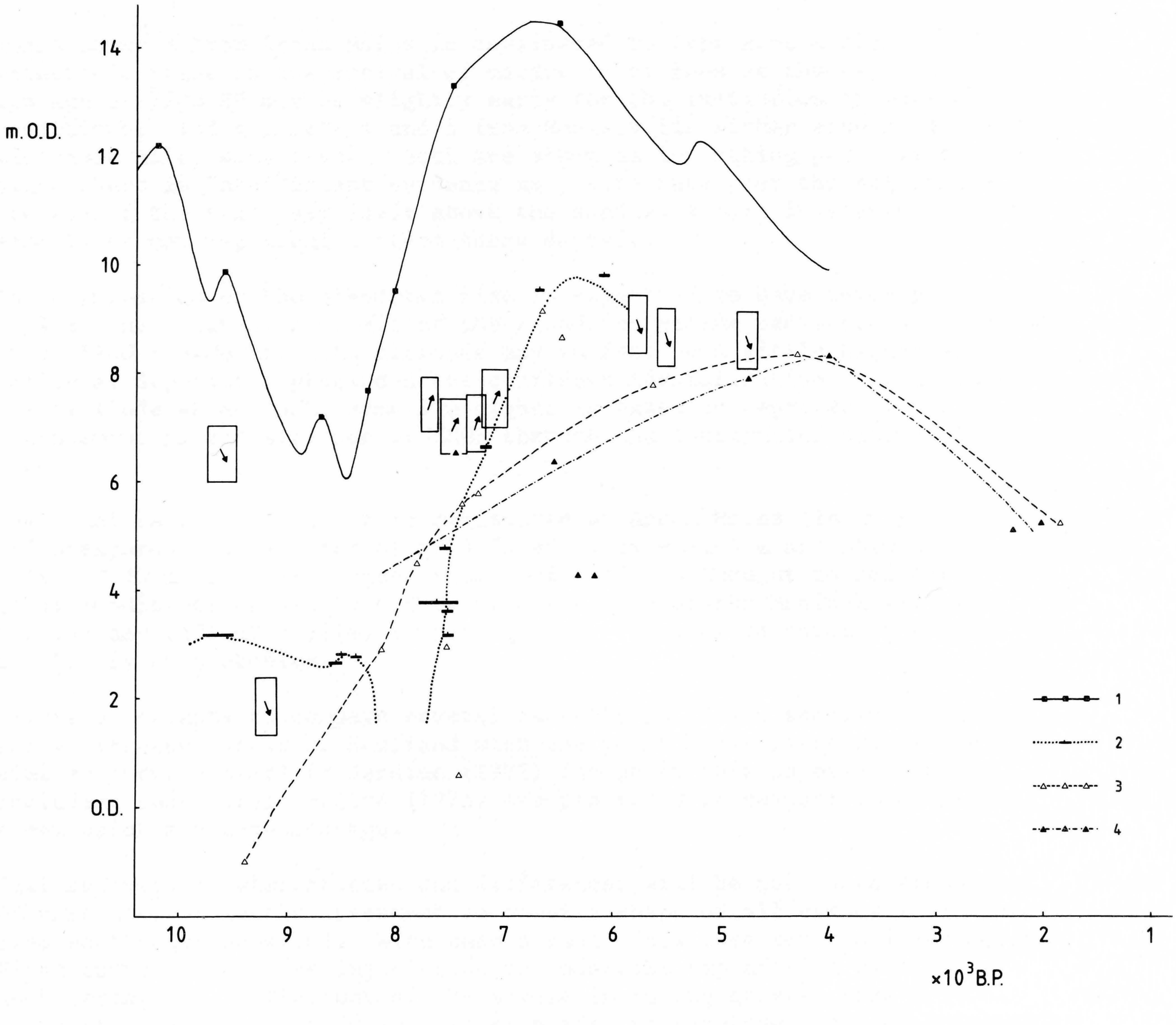

FIG. 3

Because of a lack of data points no reliable conclusions can be made concerning the initiation of the following rise in sea-level nor of the rates of rise involved. As an initial estimate, based on pollen and diatom evidence from Barnyards, sea-level was probably rising by c. 8200 BP.

Index point 3 from Arcan Mains is considered to represent a rise in watertable prior to the arrival of marine conditions at the site and its age of 7700 BP may be slightly early for the initiation of marine conditions. Index points 4 and 5 from Moniack lie either side of a grey micaceous silty sand layer. Both are shown as indicating positive tendencies since there is insufficient evidence as yet to interpret the regressive overlap of the thin peat layer above the sand as a fall in sea-level. The sand layer may represent a storm surge deposit.

The culmination of the Flandrian rise is suggested to have taken place at c. 9 m, the altitudinal limit of the Flandrian marine sediments at Barnyards, at c. 6100 - 6400 BP. The altitude may in fact be a little higher since colluvial deposition precluded the confident identification of the limit. The altitude at Moniack, some 1 m higher is taken to represent local enhancement of the altitude of MHWS through the constructed nature of the site.

The final fall in sea-level is registered at Arcan Mains (index point 7) and Barnyards (index point 8) at 5775 BP, 8.39 - 9.44 m and 5510 BP, 8.15 - 9.20 m OD. The Moniack index point (9) is thought to reflect local conditions caused by the renewed activity of the Moniack alluvial fan and may reflect a delay in peat growth. Further research is needed to clarify this problem.

Figure 3 attempts to compare several recently published sea-level curves for a different areas of Scotland with the inner Moray Firth curve. A similar curve appears in Jardine (1982) though in this paper all curves including those from Jardine (1975) are plotted with respect to original index point altitude and age.

Full analysis of similarities and differences will be published elsewhere. Of note however is the agreement in overall shape of all curves save those from south-west Scotland. With such a small data base for the inner Moray Firth curve it would be injudicious to undertake explanation with too much certainty. Refinement of the scheme including greater time control on the initiation of the main Flandrian rise in sea-level and its culmination is required before statements on the synchroneity or diachroneity of shorelines or movements in sea-level are made.

PART 1 SECTION 3

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