We now consider the land-based timescale of climatic change for deglaciation and the Holocene to date our isotope signal (Fig. 1*a*). The resulting timescale should be younger than the corresponding deep-sea radiocarbon ages, by an amount comparable to the difference between bulk- and coarse-fraction ages. Of course, the line-up of climatic changes on the land and in the sea should match closely.

Figure 1*a* is derived from stacking the signals of cores 97, 101 and 104 (Fig. 1*b*). The shape of the isotope signal is very similar to one published earlier, from the same region, based on Albatross cores[22], but without age control. The radiocarbon measurements suggest an age near 11 kyr for step 2 (point X). According to our argument, this age represents a maximum for this climatic event. The most nearly synchronous and also the younger event on land, marking a time of rapid change from cold to warm conditions, is represented by the transition from the Younger Dryas cold period to the Preboreal warm interval. Thus the 'cold spot' preceding step 2 in our signal is fixed as the Younger Dryas, which is centred on 10.5 kyr. The entire timescale is now derived by assuming zero age for the surface, and linear sedimentation rate to the Younger Dryas fix-point. With this assumption, an excellent fit is obtained with the Norden timescale[23], based on Scandinavian climatic history (Fig. 1). The differences between the set I ages and the ages found by climate correlation are of the expected magnitude (except for the benthic mixed layer proper) (Table 1, third column).

Our new timescale puts the start of deglaciation just after 14 kyr BP (instead of 15 kyr, based on raw ^{14}C data). Step 1 is centred on 13 kyr and step 2 on 10-9.5 kyr. Our deglaciation steps compare favourably with the micropalaeontological 'warming' steps of Ruddiman and McIntyre[10], established for the northern Alantic. The correlation of the deglacial pause with the Younger Dryas, a major cold event on land, was previously suggested by Duplessy *et al.*[6]. The end of the pause is at point "K", which is taken to be 10.2 kyr BP. This event fixes our timescale, by linear interpolation and extrapolation. Point K slightly predates the Ash Layer 1 of Ruddiman and McIntyre[24], dated at 9.8 kyr BP in ref. 6.

We refer to the timescale adopted in Fig. 1 as the 'K-scale'. Its veracity ultimately rests on a climatic correlation (hence K for Klima), namely, the fit of the pause between the two deglaciation steps to the Younger Dryas cold period. This correlation was first suggested to us by Johnson[25].

Major questions arising from the new deglaciation scale are: what is the positive feedback mechanism which was responsible for the steepness of the two steps; why did deglaciation pause halfway through its completion; and is the published information for ice retreat on land compatible with the deep-sea oxygen isotope record when dated in the manner shown? The evidence for pulsed meltwater input, combined with the short timescale advocated here, makes it likely that the sought-for feedback mechanisms involved intermittent slowing of vertical ocean mixing (the 'Worthington effect')[26]. Such slowing would affect the carbon dioxide content of the atmosphere[27], and hence the direction and the rate of climatic change. There is one possible way the 'early-deglaciaton' timescale[10,15] could be resurrected: if it could be shown that lack of carbonate production (for example, owing to a meltwater lid) produced a carbonate hiatus in the crucial period, near 15-16 kyr, so that a planktonic isotope signal was not recorded, even in the equatorial Atlantic.

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A prehistoric calendrical site in Argyll?

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The hypothesis that many prehistoric standing stone sites in Britain were set up, in relation to natural horizon marks, as astronomical observing instruments has been controversial for the past two decades. Although based primarily on statistical arguments, whether or not it stands will depend on the outcome of practical tests; it must prove able to predict at some sites the occurrence of archaeological features which can then be found by excavation. We report here on the findings at Brainport Bay in Argyllshire of artificial features pointing towards the midsummer sunrise that have been dated suitably early and of another feature indicating alignment towards the sunset at the equinox, that was first predicted and then discovered. These results seem to provide strong support for Thom's hypothesis that calendrically useful solar markers existed in Scotland at least as early as the Bronze Age.

At Brainport Bay, near Minard on Loch Fyne, one of us (P.F.G.) discovered in 1976 a series of artificial stone structures which were first interpreted as a settlement site, but the absence of clear signs of dwellings or of midden material made an alternative hypothesis desirable. Since then, the possibility of their forming an alignment towards midsummer sunrise has been considered, which seemed to explain several hitherto inexplicable features[1,2]. The presence of flint flakes and artefacts and of shattered quartz fragments on the various parts of the site confirmed Mesolithic or Neolithic activity, but there were also much later iron objects and slag. The supposed alignment consists of three main features running from north-east to south-west, namely the 'main outcrop' (with paving on it and two lower revetted 'terraces' at its south-west end), the 'observation boulders', 9 m further south-west and, 50 m further in the same direction, the 'back platform', a few metres higher up (Fig. 1).

From between the two boulders one has a striking view north-east up Loch Fyne, and a partly artificial rock notch at the south-west end of the main outcrop (1.38 m deep and 1.30 m wide at the top) frames the only two distant peaks to be seen—Beinn Oss and Beinn Dubhcraig, 28 miles away near Tyndrum. A small socket was found immediately in front of this notch and another up at the north-east end of the outcrop; two stone slabs 1.28 m and 1.46 m long, which fit these sockets well, were

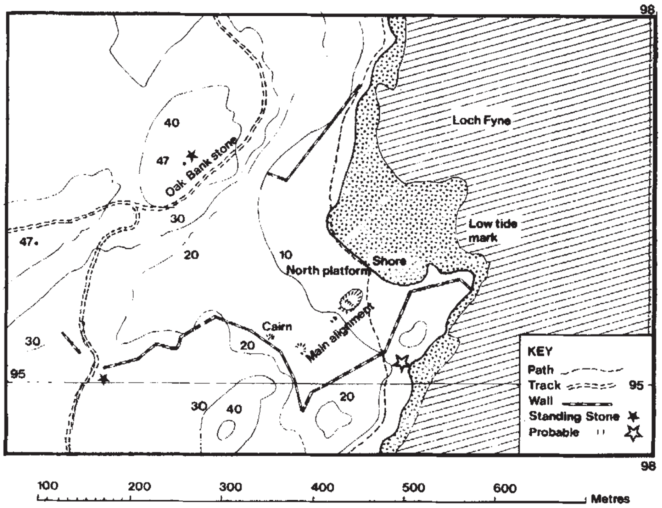

Fig. 1 General plan of Brainport Bay showing the main alignment (with the Back Platform at the south-west) and some nearby outlying features. The contours are in metres above mean sea level.

found on the buried land surface nearby. All these features—boulders, notch and sockets—lie on a straight line pointing to the mountain peaks behind which the midsummer Sun rises (see Fig. 3.5 in ref. 2). The arrangement looks like the sights of a huge rifle aimed at the solstitial Sun, but to be of practical as opposed to ceremonial use, the cleft between the two peaks would have to have been used. Measurements by Thom showed that this cleft has a declination of +23°22′, slightly before the solstice of 1800 BC; then it would have marked the upper limb of the Sun rising on two occasions about 32 days apart, before and after midsummer (see p. 134 and Fig. 3.8 in ref. 2).

The third element in the alignment, the back platform, consists of a rock outcrop on the northeastern edge of higher ground and that has been modified with revetting and paving; there is a broad flat area behind it. From here there is a dramatic, though generalized, view of the midsummer dawn, but not through the rock notch, which is now too low.

Excavations in 1982 revealed a buried sandy soil behind the back platform on top of which were struck flint flakes; a ^{14}C date of 1060±80 BC (GU 1705) was obtained for charcoal associated with the flints, equivalent to the fourteenth century BC in calendar years[3]. The revetted edge of the larger terrace next to the main outcrop was found to lie on the same buried soil (Fig. 2). Thus, the artificial elements of the main alignment have been fairly securely dated to the mid-second millennium BC or earlier. Excavations at the 'observation boulders', however, showed that, contrary to previous belief (see p. 134 and plate 3.6 in ref. 2), these have been in position since the time of the post-glacial high sea level, well before Neolithic times.

As it does not point exactly at the solstice, the calendrical function of the main alignment had to remain speculative, unless another clearly-indicated and reasonably precise alignment could be identified nearby; this could serve as a double check on any solar calendar and would tend to confirm that one was in use. The most probable candidate for a second alignment was the fallen stone on the ridge above Oak Bank, ~240 m north-west of the main alignment.

An attempt in 1981 to discover whether the Oak Bank stone could have been an artificial foresight to mark the midsummer sunset, as seen from the large terrace, resulted in the discovery, as a potential backsight, of the small stone North Platform a few metres north of the main outcrop and in the appropriate position; excavations in 1982, however, showed it to be relatively modern. It then seemed appropriate to test whether the fallen stone on Oak Bank might itself have been the backsight for an alignment.

One of us (P.F.G.) had found previously two unusual rock carvings a few metres south-east of the fallen Oak Bank stone, among the dense firs of a Forestry Commission plantation. Each consists of a pecked cup-mark of standard early Bronze Age type, but with a straight shallow pecked groove running through it (Fig. 3). Carving no. 1 has a groove ~60 cm long, on an azimuth of 130.5/310.5°, and points directly back at the Main Outcrop below. Carving no. 2 has a groove ~40 cm long on an azimuth of ~81/261°, ~2.1° greater than the line defined by the two cup-marks themselves. These directions can be determined to within ~0.5° using a prismatic compass checked against a line of known azimuth.

The many fir trees around the carvings obscure the western and northwestern horizons; the groove of no. 1, however, was found to point at a featureless horizon several degrees to the right of the midsummer sunset position. The near east-west orientation of no. 2 suggested that it might mark an equinoctial line, the backsight for which would be the fallen stone nearby, but the eastern horizon across the loch is flat and featureless. Nothing could be seen of the western horizon at first until the azimuth of the groove was transferred 20 m to the base of the fallen stone; it then pointed almost exactly at a deep V-shaped notch ~1 km away in Siaradh Druim, the 'western ridge'. A metal rod laid in the groove of the rock carving confirmed, after some clearance of branches, that it points at this notch. This notch has an azimuth of 261°32.5′ and a declination of +0°08′ as seen from the stone (perhaps +0°04′, if the trees on the left slope are removed) (Fig. 4).

This position is within the range of the declinations of equinoctial sites identified by Thom, the mean of which is approximately at the 'megalithic equinox' of +0.51° (ref. 4). This is the date that would have resulted if the equinox was defined by counting the days in the year and sub-dividing (the summer half being a few days longer because of the eccentricity of the Earth's orbit (see p. 109 in ref. 4)). The Oak Bank alignment could have defined this megalithic equinox very well, if the Sun's lower limb served as the marker against the horizon. Figure 4 shows the 24′-wide zone of fluctuation—the amount

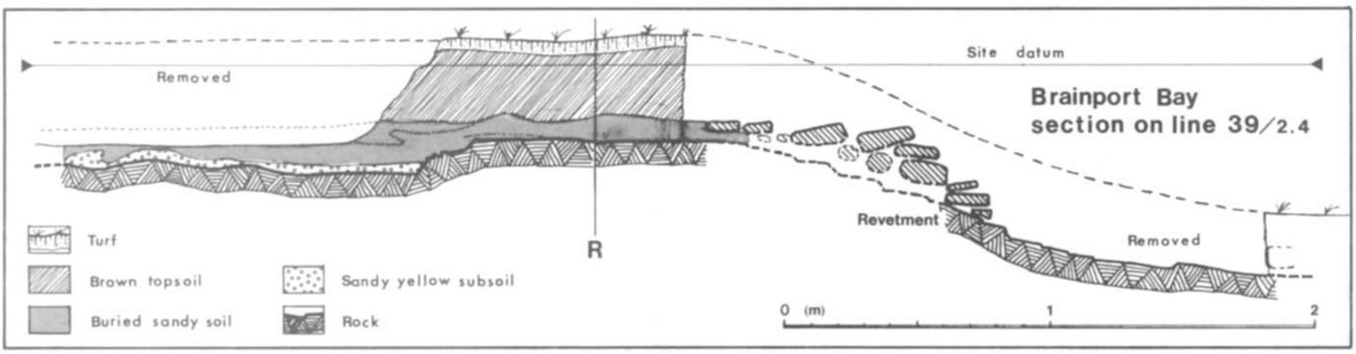

Fig. 2 Section of soil layers on the northwestern edge of the large terrace at Brainport Bay, showing the revetment of the terrace lying on the prehistoric ground surface.

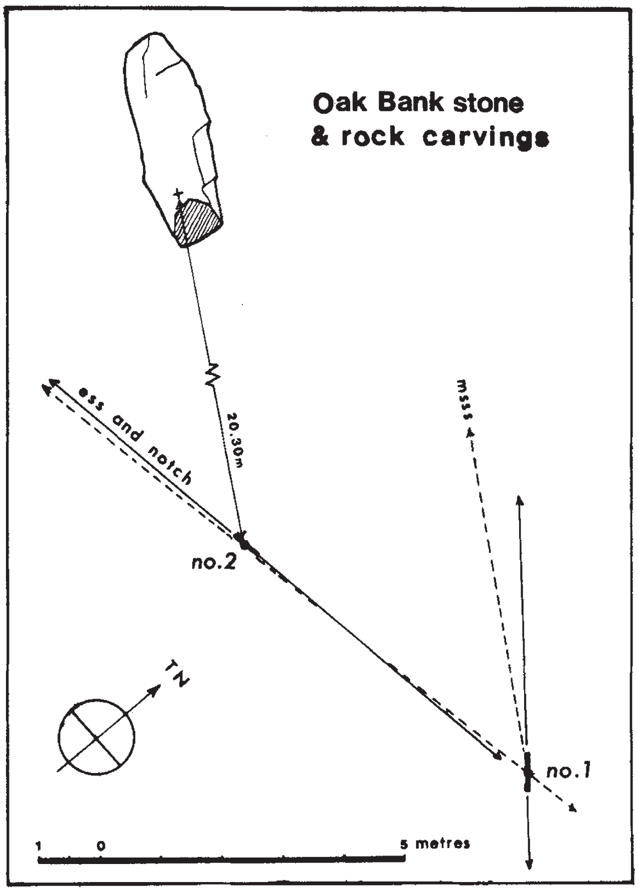

Fig. 3 Plan of artificial features on Oak Bank—the fallen stone and the two rock carvings. Carving no. 1 points back to the main site at a distance of 225 m. 'ESS' means equinoctial sunset and 'MSSS' midsummer sunset.

by which the solar declination can vary at sunset at the equinoxes—against the notch. Thus, the first appearance of the full disk in the notch in the spring, and the last in autumn, would have marked the day of the megalithic equinox and the alignment could have served as a good check on a solar calendar.

Ideas about the achievements of prehistoric man in Britain have focused traditionally on his technological and economic skills, deducible directly from the archaeological evidence; ceremonial and religious practices are much harder to recover but seemed to have been suitably primitive[5,6]. However, much evidence from Thom shows that late Neolithic people erected standing stones to mark the position of the Sun and Moon (and some stars) on the horizon at important points of their cycles and that they thereby developed considerable astronomical expertise (see chapter 9 in ref. 4). These ideas have aroused considerable interest and controversy[7–11].

The particular aspect of the Thom hypotheses examined here is that many standing stones marked the 'backsights' (observers' positions) of alignments that could detect when the Sun was at the solstices, equinoxes and at other important intermediate dates of the solar calendar. These lines point towards 'foresights', which are natural marks on the horizon where the Sun rose or set at the times concerned and which are usually indicated in some way by the stones themselves.

The evidence assembled consists of a large number of standing stones, which could have been the backsights for such accurate alignments in Neolithic times, and of the statistical argument that this could not have happened by chance (ref. 12 and see chapter 8 and Fig. 8.1 in ref. 4). There has been much argument about whether such deliberately arranged astronomical lines (on which the more elaborate astronomical hypotheses developed by Thom (concerning the Moon) ultimately depend[4,13,14]) were actually intended to be such by the standing stone erectors, about how accurate they were and for what exactly they were used[10].

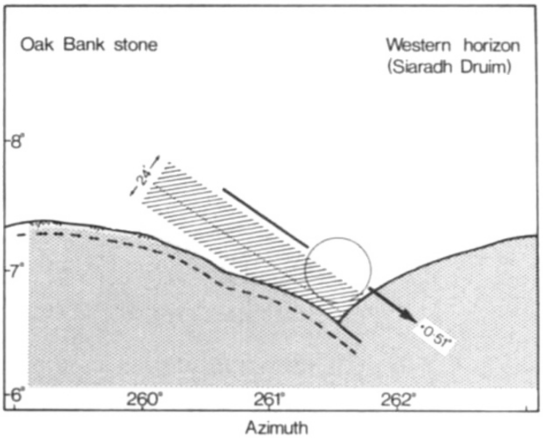

Fig. 4 Siaradh Druim, the 'western horizon', as seen from the Oak Bank stone with the Sun at the 'megalithic equinox'; the dotted line indicates where the real horizon may be, below the tree line. The shaded band shows the range of possible positions for the lower limb at sunset at that time.

It can be argued that the genuineness, or otherwise, of the alignments will only be finally settled by testing a selection of examples on the ground, that is, by finding sites where one of the astronomical alignment hypotheses predicts the existence of some feature that can then be sought by excavation[15,16]. One of us (E.W.M.) attempted to do this at the Kintraw standing stone in mid-Argyll, where an artificial platform was discovered, as required by Thom's theory that a precise midwinter sunset alignment existed there[17]. However, as the platform could not be dated, the evidence was inconclusive.

The results from Brainport Bay described here suggest that, at this site, there are two well-marked prehistoric solar alignments, the reality of which has been demonstrated beyond reasonable doubt and which could therefore be interlinked. The conspicuous line towards midsummer sunrise is formed by clearly artificial and by natural features and it has been dated as suitably early, directly, from associated artefacts and indirectly, from a ^{14}C measurement. Yet the discovery that the 'observation boulders' are natural, implies that the alignment began as the chance finding of a suitable site with a long view to the north-east (presumably by people searching for one) and that features on it were modified to form a line towards the midsummer sunrise. This could explain why the 'foresight' mountains, though suitably distant, are not the ideal shape for marking the solstitial sunrise exactly; in other such cases, the Sun's upper limb rose or set along one slope, about parallel to the angle of its diurnal movement (see Fig. 12.2 in ref. 4).

This in turn suggests that the prominent north-east alignment was intended as much for ceremonial as for calendrical purposes; certainly the dawn spectacle is dramatic and could have been viewed by many people. It may also have been a useful calendrical alignment; the date of the solstice could have been found at any period in the past by halving the interval between successive risings in the notch. However, such an indirect alignment is less convincing statistically than one that points exactly at the solstitial declination, hence the search for a second solar line at the site.

Such a solar line, indicating the equinoctial sunset, was found at the Oak Bank stone rock carvings. Because of the obscuring fir trees it is also a good example of the discovery of a convincing alignment through a prediction made from Thom's general solar alignment hypothesis. On such independent testing of potentially accurate astronomical alignments as this depends surely the fate of ambitious re-assessments of the skill and organization of late Neolithic society in Britain[18], and indeed that of the traditional views also[5,6].

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The first pre-Rhaetic therian mammal

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The earliest mammals in the fossil record are recognized by their multicusped and multiple-rooted cheek teeth, and in south-west Britain they appear abruptly in sediments that postdate the Rhaetic transgression at ~200 Myr. Here we report the discovery of teeth of the primitive mammal *Kuehneotherium* in a terrestrial fissure deposit from the Mendip Hills (Somerset, UK) that predates the Rhaetic transgression. The teeth were found in the sediment fill of a collapsed cave[1] at Emborough near Wells during the systematic reinvestigation of a number of late Triassic vertebrate sites. The assemblage is otherwise typically pre-Rhaetic and includes the gliding lizard *Kuehneosaurus*. The finding of mammalian remains throws doubt on the fundamental distinctiveness of pre-Rhaetic and post-Rhaetic vertebrate faunas.

Vertebrate-bearing fissure deposits are known at several sites in the Lower Carboniferous/Mesozoic unconformity either side of the Severn Estuary (Fig. 1). The fissures comprise a variety of features including karstic cave systems, tectonic joints and faults; their fills range from Triassic continental red marls to middle Jurassic marine limestones. In the first major review of the nature and occurrence of fissure deposits, Robinson[1] distinguished between Norian and Rhaeto-Liassic deposits which she believed could be recognized on the basis of their vertebrate faunas[2]. The Norian fauna consisted entirely of sauropsids whereas the Rhaeto-Liassic faunas contained theropsids and mammals in addition to sauropsids. There was also some variation in the nature of the sauropsid fauna, particularly with respect to archosaurs, which occurred only rarely in the Rhaeto-Liassic deposits. This broad division has been accepted by subsequent authors. Typical Norian assemblages include *Clevosaurus*, *Kuehneosaurus*, *Planocephalosaurus*, primitive crocodiles and pseudosuchians[3-5], whereas the Rhaeto-Liassic forms include *Morganucodon*, *Kuehneotherium* and the lepidosaur *Gephyrosaurus*[6-8].

More recently, Marshall and Whiteside[9] have identified marine Rhaetian palynomorphs in sediments at Tytherington Quarry which contain a typical Norian sauropsid fauna, including *Clevosaurus* and *Planocephalosaurus*[10]; this work did not question the existence of two distinct faunas, but threw doubt on the validity of assuming an age prior to the Rhaetic transgression for the sauropsid assemblages. We have confirmed the presence of datable palynomorphs in the Tytherington sequence, but their usefulness is open to question as the deposits are contained within tectonically generated fissures which have suffered more than one phase of disturbance and mixing of the contents.

The Emborough deposit has yielded no palynomorphs and cannot be dated in this way, a problem in common with late Triassic continental sediments elsewhere[11]. The deposit consists of a single large pocket of poorly sorted, locally derived limestone boulders and coarse conglomerate set in a matrix of red marl. The pocket has been interpreted as a collapsed cave deposit[1], and the conglomerate and marl components are typical pre-Rhaetic lithotypes; no Rhaetic or post-Rhaetic clastic components can be recognized. Further evidence of the pre-Rhaetic age of the Emborough deposit is provided by nearby outcrops of basal Rhaetic sediments which overlie a formerly planar transgression surface. This surface now rises southwards, and clearly extended across the top of the Emborough pocket.

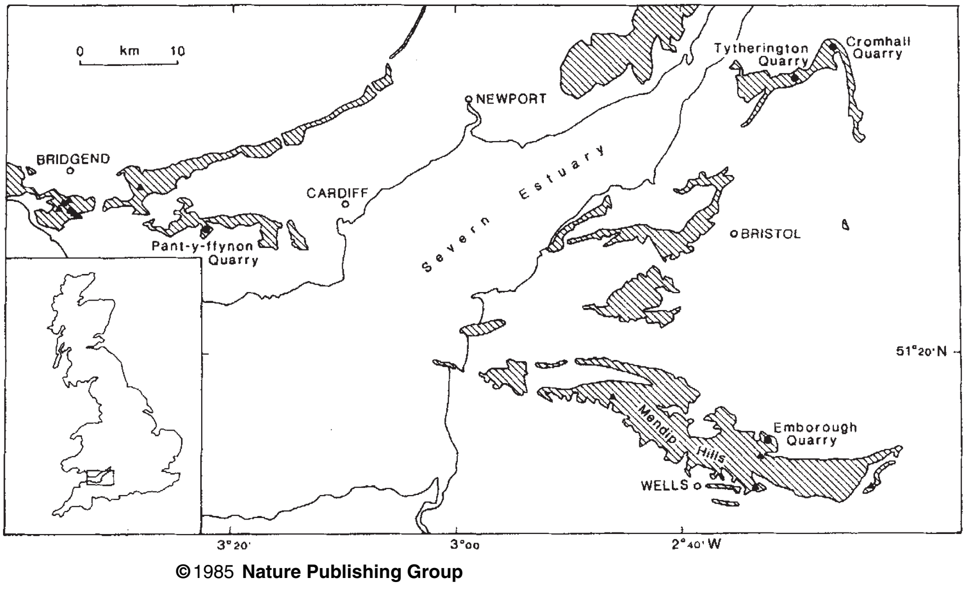

Fig. 1 Vertebrate-bearing Triassic fissure deposits either side of the Severn Estuary, UK. ▨, Carboniferous limestone outcrops; ●, localities mentioned in the text; ▲, other known localities.