

The Mesolithic-Neolithic transition in western Scotland and its European context¹

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ABSTRACT – *The transition is considered in terms of four related questions: (i) HOW did the shift from foraging to farming happen? (ii) WHY did it happen? (iii) WHEN did it happen? (iv) WHY did it happen WHEN it did? The adoption of farming coincided with a shift to a more continental-type climate with lower winter precipitation, which improved the prospects for cereal cultivation. It is suggested that this was a key factor in the transition from Mesolithic to Neolithic across north-west Europe as a whole.*

IZVLEČEK – *Mezolitско-neolitски prehod obravnavamo glede na štiri povezana vprašanja: (i) KAKO se je zgodil prehod iz lovstva-nabiralništva v kmetovanje? (ii) ZAKAJ se je zgodil? (iii) KDAJ se je zgodil? (iv) ZAKAJ se je zgodil, KO se je zgodil? Do prevzema kmetovanja je prišlo v času, ko so klimatske razmere postale bolj kontinentalne in zimske padavine manj obilne. To je izboljšalo pogoje za gojenje žit. Menimo, da je bil to ključni dejavnik za prehod iz mezolitika v neolitik v celotni severozahodni Evropi.*

KEY WORDS – *Mesolithic; Neolithic; transition to farming; Scotland; Northwest Europe*

INTRODUCTION

The Mesolithic and Neolithic have figured prominently in the literature on Scottish prehistory, but almost invariably have been treated separately. Comparatively little has been written about the actual *transition* from one to the other. This may seem surprising given that the Mesolithic-Neolithic transition was a time of fundamental economic, social and technological change.

The reason is not hard to identify. Archaeologists have tended to specialize in one period or the other, and in the process have developed very different approaches and theoretical frameworks. While Mesolithic specialists have concerned themselves largely

with economic and technological issues, Neolithic specialists have placed much more emphasis on social questions. The result is a conceptual divide (*cf. Thomas 1988*) across which little interaction takes place and which, in effect, has acted as a barrier to research.

This paper is an attempt to bridge that divide and to provide a fresh perspective on the subject. It looks at the transition from Mesolithic to Neolithic in terms of four related questions: (i) *How* did the shift from foraging to farming happen? (ii) *Why* did it happen? (iii) *When* did it happen? (iv) *Why* did it happen *when* it did?

1. This paper was presented at an international conference in Edinburgh in November 1999 on the theme, Mesolithic Scotland: the Early Holocene Prehistory of Scotland and its European Context. Whilst the text has not been revised, the opportunity has been taken to update the bibliographic references.

HOW DID IT HAPPEN?

There are two competing (but not necessarily mutually exclusive) explanations of the spread of agriculture into the British Isles and, ultimately, western Scotland. One is that it occurred primarily through colonization by immigrant farmers (*e.g. Case 1969; Bradley 1984*). The alternative is that it came about through a process of 'neolithization' – the transfer of ideas, resources and technology to the indigenous Mesolithic population from Neolithic farming communities on the European mainland (*e.g. Dennell 1983; Kinnes 1985; Williams 1989; Thorpe 1996; Whittle 1999*).

The immigration model

The immigration model rests on three principal lines of evidence: (i) the apparently abrupt disappearance of Mesolithic culture and its replacement by new forms of artefacts, burial customs and monumental architecture with clear parallels on the continent, (ii) the strong temporal coincidence between changes in economy and material culture, and (iii) the lack of settlement continuity across the Mesolithic-Neolithic transition.

The strongest argument for colonization from mainland Europe lies in the broad similarity of the Neolithic between the two regions. Though there are precedents on the Continent for the monument types and some of the portable artefacts that characterize the Early Neolithic of Britain and Ireland, it has always proved difficult to identify the specific region, or regions, from which colonists would have entered the British Isles.

Other key elements of the immigration model are also open to question. Abrupt culture change and settlement relocation are not *proof* of the arrival of a new people. Rather, it can be argued that they were a predictable outcome of the economic transformation that characterized the Mesolithic-Neolithic transition, regardless of the demographic context. Hunter-gatherers taking up agriculture can hardly be expected to have done so equipped only with their existing Mesolithic toolkit, which was not designed for the purpose. There would be a need to invent or adopt new technology. Moreover, if agriculture were the primary means of food production from the beginning of the Neolithic – as appears to have been the case in western Scotland, if not throughout the British Isles – then people are likely to have invested heavily in the new technology from the outset,

and much less in forms of technology related exclusively to hunting, fishing and gathering which were of lesser economic significance. In general, people will invest more in those aspects of their technology that they regard as critical for survival. For example, the disappearance of the 'T-shaped' axes of red deer antler (Fig. 1A) that characterized the later Mesolithic of Scotland, and their replacement in the Early Neolithic by ground stone axes (Fig. 1B), probably reflects an increased investment in technology for clearing woodland and constructing fences around field plots. A stone axe may have been more expensive in terms of material and labour 'costs', but was probably more efficient and more durable. Conversely, the abandonment of microlithic technology and the introduction of the leaf-shaped arrowhead may be seen as a response to the decline in the economic importance of hunting in the Early Neolithic. An arrow tipped with a single leaf-shaped point was probably easier and quicker to make and maintain than one fitted with numerous microlithic armatures.

The apparent lack of settlement continuity is also inadequate evidence for the immigration model. Just as subsistence activities affect technology, they also influence settlement location. Use of the same sites is likely to have occurred only where conditions for Mesolithic and Neolithic settlement coincided. This point is well illustrated by the situation in the Iron Gates gorge on the River Danube (*Bonsall et al. 1997a*). In the Iron Gates fish and other riverine resources were of considerable economic importance in both the Late Mesolithic and Early Neolithic, while land suitable for habitation was restricted to narrow terraces bordering the river. It is not surprising, therefore, to find frequent examples of sites on these terraces that were occupied during both periods. In western Scotland, on the other hand, although 'settlement space' was often constrained by the hilly terrain, there were substantial differences in subsistence practices between Late Mesolithic and Early Neolithic. Mesolithic communities relied on the sea and the littoral zone for most of their food supplies, and their settlements show a strong preference for near-shore locations in sheltered marine inlets (*Johnson and Bonsall 1999*). These conditions were probably less important in the Early Neolithic when, in the context of an economy dominated by agriculture, proximity to land suitable for cultivation and livestock raising would have been a greater priority than direct access to the coast. There are, however, instances in western Scotland where favourable conditions for Mesolithic and Neolithic settlement did coincide and where archaeological remains of both

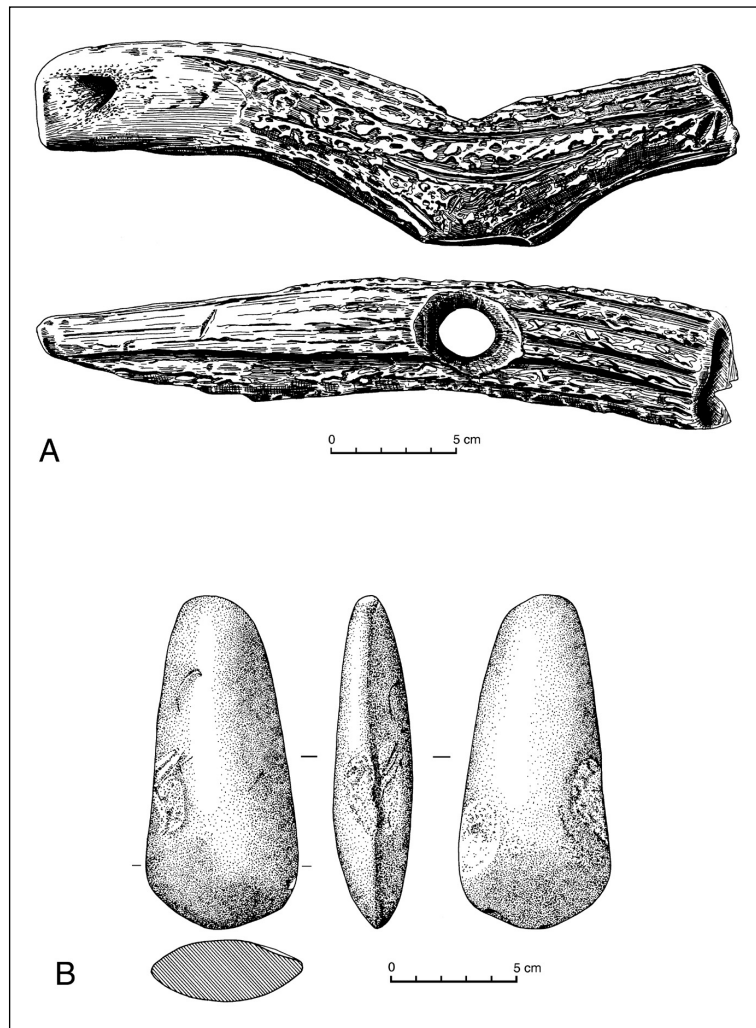


Fig. 1. A – Late Mesolithic T-shaped axe of red deer antler from Meiklewood, near Stirling (after Bonsall and Smith 1990) – a functional analysis of similar antler axes from Denmark (Jensen 2001) has shown convincingly that they were tree-felling and/or wood-working implements. B – Neolithic ground stone axe from the Isle of Ulva, Argyll. Drawn by Gordon Thomas.

periods occur. The Kinloch site, on the island of Rhum, occupied a sheltered position, near to fresh water, at the head of a narrow inlet where reasonably well-drained soils suitable for cultivation are also found (Wickham-Jones 1990). In major coastal valleys of the mainland and larger islands, with more extensive areas suitable for early agriculture, Mesolithic settlements tend to occur at the coast, while later farming settlements are located further inland. These relationships are well demonstrated in the Oban area, Argyll (Bonsall *et al.* 1997b; Macklin *et al.* 2000).

The neolithization model

Among the arguments advanced in support of the 'neolithization' model are that there is no obvious

area of origin for British Neolithic culture on the European mainland, that at least some elements of British Early Neolithic technology (e.g. the leaf-shaped arrowhead) were developed locally, and that the spread of farming across the British Isles was too rapid to be explained simply in terms of immigration followed by population expansion (Kinnes 1985). These are all valid points. However, other arguments used to support the neolithization model are less persuasive.

For example, it has been suggested that the Early Neolithic of the British Isles was characterized by residential mobility and a continued reliance on wild food resources, indicating a substantial degree of economic and social continuity with the Late Mesolithic (e.g. Thomas 1991; Armit and Finlayson 1992; Whittle 1999). This argument is unconvincing because, although hunting and gathering were practised – in fact, they were almost universal among the early agricultural societies of Europe – there is no evidence that they were the dominant component of the Early Neolithic economy in any part of the British Isles. Similarly, the case for residential mobility rests not on actual data but on the lack of evidence for 'large' dwelling structures that are considered to be indicators

of sedentism. How Early Neolithic sites such as Balbridie in Aberdeenshire (Fairweather and Ralston 1993) and Lismore Fields in Derbyshire (Garton 1987) and Late Mesolithic sites such as Williamson's Moss in Cumbria (Bonsall *et al.* 1989) can be accommodated within the residential mobility hypothesis is not adequately explained!

Likewise, the so-called 'Obanian' shell middens of the west coast of Scotland are sometimes claimed to show evidence of 'settlement' continuity across the Mesolithic-Neolithic transition (e.g. Armit and Finlayson 1992; Thorpe 1996). This evidence needs to be put into perspective. The middens are refuse heaps resulting mainly from food processing activities, but were probably not directly attached to settlements. Most likely, they represent places some di-

stance from a settlement where small groups of mainly women and children came to collect shellfish from the littoral zone, sometimes combined with line fishing from the shore. The shellfish and fish collected were processed at the sites, with the meat being taken back to the settlement for consumption or storage (Bonsall 1996). Individual 'processing sites' may have been used regularly, possibly annually, each visit lasting perhaps less than a day. This would represent a logical strategy for shellfish gathering along the central-west coast of Scotland. Remains of shellfish that inhabit rocky shores, such as limpets, periwinkles and dog-whelks, dominate the middens. Such shellfish constitute a highly dispersed resource that is exploited most efficiently at different points along the shoreline. Attempts to gather shellfish frequently from only one location (adjacent to a settlement, for example) would rapidly deplete the local shellfish population. Thus, it is likely that an individual settlement would have had a number of outlying shellfish gathering-and-processing sites.

This pattern of shellfish exploitation appears to have been practised throughout the later Mesolithic of western Scotland; it may also have been practised during the Neolithic and in later periods. Equally, however, the same basic strategy was employed by archaeologically- and ethnographically-known shellfish gatherers in many parts of the world (Meehan 1982; Waselkov 1987) – evidence that different people will often arrive at similar solutions to the same basic problem. Thus, the existence of shell middens in both the Late Mesolithic and Early Neolithic of western Scotland cannot be used as evidence of demographic continuity from one period to the next.

In any event, although some 'Obanian' shell middens were added to over hundreds of years (Bonsall 1996) there are very few sites that show evidence of Late Mesolithic and Early Neolithic activity. Only two examples come to mind – Ulva Cave near Mull (Bonsall et al. 1994; Russell et al. 1995) and An Corran rockshelter on Skye (Saville and Miket 1994) – but in neither case is it possible to demonstrate continuity of use across the Mesolithic-Neolithic transition. Caves are more or less fixed points in the landscape that

were convenient natural shelters for various kinds of past human activity (cf. Bonsall and Tolan-Smith 1998). Therefore, the presence of Mesolithic and Early Neolithic remains may owe more to the existence of the cave than to any biological or cultural connection between successive groups of occupants. Much the same argument applies in those instances where caves containing Mesolithic shell middens were later used as burial chambers (Bonsall et al., n.d.; Saville and Hallén 1994).

Shell middens do, however, provide a possible example of technological continuity between Late Mesolithic and Early Neolithic in the form of the *bevel-ended tools* of bone, antler and stone that occur in many sites (Fig. 2). These artefacts were almost certainly used for harvesting limpets (Griffitts and Bonsall 2001), rather than skin-working tools as suggested by Finlayson (1993; 1995). Direct dating of examples from a number of sites in Scotland has shown that their use was not confined to the Mesolithic, but continued through the Neolithic and into the Bronze Age (Bonsall and Smith 1990; Bonsall et al. 1995; Saville, *in press*). However, the bevel-ended tool is a very simple, expedient device that may have had a wide distribution around the coasts of Britain. It may also have been used by Mesolithic people elsewhere in Europe, and very similar tools are known from prehistoric shell middens in various parts of North America (Johnson and Bonsall 1999). Therefore, it is debatable how much reliance can be placed on this artefact form as an indicator of cultural or technological continuity.

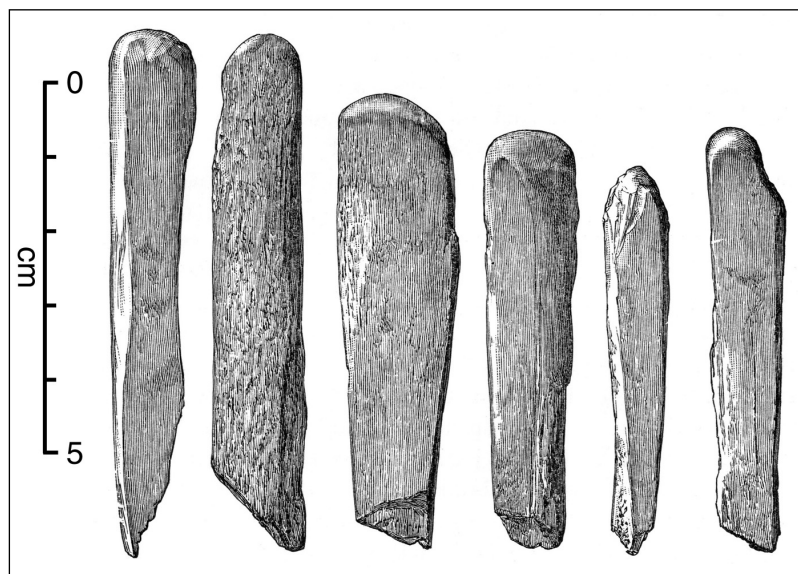


Fig. 2. Examples of bone bevel-ended tools from a Mesolithic shell midden in Drummargie Rockshelter, Oban, western Scotland (reproduced from Anderson 1898, figs. 10–15).

To summarize, at present archaeological data are insufficient to establish which of the two main competing hypotheses of the origins of agriculture in western Scotland is correct. On balance, the evidence appears to favour the 'neolithization' model, although this needs to be tested against new and better data. Potentially, analysis of ancient human DNA could show whether there was a significant degree of biological continuity between the Late Mesolithic and Early Neolithic populations of the region. Currently, however, this line of enquiry is severely constrained by the scarcity of human skeletal material from Mesolithic sites.

WHY DID IT HAPPEN?

If indigenous Mesolithic people *were* largely responsible for the introduction of agriculture into the British Isles, including western Scotland, *why* did they choose to adopt agriculture? What were the conditions that persuaded hunter-gatherers to become farmers? This question applies equally to other areas along the Atlantic façade of Europe where hunter-gatherers are believed to have played a dominant role in the transition to agriculture (Dennell 1983; 1985; Zvelebil and Rowley-Conwy 1986).

It is often assumed that hunter-gatherers turned to agriculture simply in order to increase or improve their food supply. Williams (1989:518) argued that Mesolithic people in the British Isles adopted cereal cultivation out of a desire to increase the level of carbohydrate in their diet. Others have seen the need for a 'forcing' mechanism. A popular scenario is that an imbalance between population and food supply caused by an increase in the number of people, a decline in the availability of wild resources, or both, forced the adoption of farming (Binford 1968; 1983; Cohen 1977; 1989; Cohen and Armelagos 1984; Rowley-Conwy 1984; Harris 1990).

Implicit in such models is the presumption that early agriculture offered significant advantages over hunting and gathering as a mode of food production. Farming is considered to be more productive, more reliable and less arduous. These assumptions may all be questioned. *Intensive* farming may be more productive than hunting and gathering but from the time agriculture was first attempted by a Mesolithic population it could have taken years, if not generations, for the system to become securely established.

Agriculture also requires considerable investment of time and effort, whereas ethnographic studies have shown that hunter-gatherers, even in marginal environments, usually do not need to work more than two or three days a week in order to feed themselves (Lee 1968; Woodburn 1968). Moreover, agricultural societies are just as likely as hunter-gatherers to face food shortages, especially in areas where the weather was unpredictable. Severe storms can badly damage crops, and prolonged drought can destroy the entire food supply. Equally, by virtue of being concentrated into relatively small areas, crops and livestock are more vulnerable to disease than are wild animals and plants.

Over much of Europe there is no evidence for long periods of co-existence between hunter-gatherers and farmers. In those areas where environmental conditions were conducive to cereal cultivation and stockraising, it seems that Mesolithic people took up farming soon after it became available to them. In some other regions of the world, however, there is evidence that hunter-gatherers lived in proximity to farmers for thousands of years without themselves becoming farmers. According to Ames and Maschner (1999) the native people of southern California lived near to the ancient farmers of southern Arizona for almost two millennia, engaged in trade for agricultural products, yet *never* adopted farming.

It is interesting to consider how conditions in Europe may have differed from those in California. An obvious difference is that in North America early farming economies were based primarily on domesticated plants.² Turkeys (derived from Mexico) and dogs were the only domesticated animals, but appear to have made little contribution to diet. In contrast, animals (cattle, pigs, sheep and goats) were much more important in early European agriculture. Not only did they contribute significantly to diet; they were also a potential source of wealth – an asset that could be 'owned' and controlled by households or individuals, rather than whole communities, and in ways that wild resources could not. It would seem likely that the new domesticated animal species were the main attraction of the west Eurasian mixed farming 'package' for Mesolithic hunter-gatherers. They represented not just additional sources of food and raw materials, but afforded new opportunities for the acquisition of wealth and power with all its social consequences. In this respect,

2. The major cultivated plants (maize, beans and squash) were originally domesticated in Mesoamerica, but one species of squash (*C. pepo*), several grasses, and the Jerusalem artichoke were domesticated independently in eastern North America.

if no other, the Mesolithic-Neolithic transition can be viewed as a 'social' as much as an economic event. In order to keep livestock, people must have the means to sustain them. This involves the provision of adequate supplies of water and food. In particular, considerable effort has to be put into the production and storage of fodder for winter. Leaf gathering was a probable component of the Early Neolithic farming system and may have been an important source of winter fodder, especially in areas that were marginal for agriculture. But additional supplies would need to be *grown* in the form of grass or cereals. Cereals are particularly valuable. The grain is an important storable food source for humans as well as animals, while the straw can be used for animal feed and bedding. Thus the prospects for livestock husbandry (and human subsistence) are significantly enhanced if cereals can also be grown. Therefore, the importance of adopting the entire mixed farming 'package' is clear, even if the main motivation for the Mesolithic-Neolithic transition was the desire to procure domestic animal herds.

Recalling Kinnes's (1985) comments on the rapidity with which agriculture appears to have spread throughout the British Isles, there is an important corollary of the model presented above. That is, if indigenous hunter-gatherers rather than immigrant farmers were the agents of economic change, then an important control on the expansion of agriculture was the rate at which livestock could be bred (a matter of years) and traded. On the other hand, if immigrant farmers were the agents of change, then the rate of agricultural expansion would be more dependent on human population growth and ability to colonize new areas (decades to centuries). Under the latter scenario, the spread of agriculture across the British Isles is likely to have been more uneven and gradual than is suggested by the archaeological record, especially if indigenous peoples resisted the advance of immigrant farmers in certain areas. Of course, other factors such as climate and soils also would have been strong controls on agricultural expansion.

WHEN DID IT HAPPEN?

From the preceding discussion, it follows that an understanding of the timing of the Mesolithic-Neolithic transition is essential in evaluating the arguments

for both 'how' and 'why' the transition occurred. In this section three sources of evidence for identifying the adoption of agriculture are considered: (i) ^{14}C dates for archaeological finds; (ii) dietary tracing of human bone; and (iii) palynological data.

Radiocarbon evidence

When researching this paper, the authors collated all available (*c.* 400) published or archived ^{14}C determinations for purportedly Late Mesolithic and Early Neolithic archaeological contexts in Scotland with mean ages between 6000 and 4500 BP. Radiocarbon ages have been converted into approximate calendar dates using the CALIB (rev. 4) calibration program developed at the University of Washington, Seattle (*Stuiver and Reimer 1993*). The conversion is summarized in Table 1.³

^{14}C age BP	cal BC age
4500	3200
4600	3350
4700	3450
4800	3550
4900	3650
5000	3800
5100	3950
5200	4000
5300	4100
5400	4300
5500	4350
5600	4400
5700	4500
5800	4650
5900	4750
6000	4900

Tab. 1. Radiocarbon date calibration table for the period 6000–4500 BP (cal BC ages rounded to 50 years).

Taking a very critical view of the radiocarbon evidence, ^{14}C dates falling into the following categories may be regarded as suspect:

- ① isolated dates
- ② dates with very large errors ($>\pm 2\%$)
- ③ dates that are 'outliers' in an otherwise coherent series
- ④ dates on charcoal samples where there is a distinct possibility of inclusion of 'old wood' or residual material
- ⑤ dates on material of uncertain cultural affinity
- ⑥ dates that are inconsistent with *either* the stratigraphic context *or* archaeological associations.

3. Dates quoted in 'cal BP' years in this paper are taken from publications where the original ^{14}C age estimates were not given.

Treating only the remaining dates as reliable permits the following general observations:

- ① Evidence from the Oban area (*Bonsall et al. 1997b*) suggests that Mesolithic technology in the form of narrow blade microliths was still in use on the west Scottish mainland *c.* 5300 BP (4100 cal BC)
- ② There are no secure dates for field monuments or for contexts with pottery or other distinctively Neolithic artefacts from any part of Scotland significantly older than *c.* 5000 BP (3800 cal BC)
- ③ The earliest *direct* evidence for agriculture in Scotland is provided by AMS dates on charred cereal grains from Balbridie, Aberdeenshire (*Fairweather and Ralston 1993*) and Balfarg Riding School, Fife (*Barclay and Russell-White 1993*) of between *c.* 4940–4830 BP (3730–3600 cal BC) (Fig. 3A).
- ④ On this evidence, the transition from Mesolithic to Neolithic in Scotland occurred sometime between 5300 and 4900 BP (4100 and 3650 cal BC).

A critical appraisal of the available radiocarbon dates for Late Mesolithic and Early Neolithic sites in England and Wales shows a broadly similar pattern. There is good evidence for the continuation of microlithic technology until *c.* 5300 BP (4100 cal BC), while there is no convincing evidence for Neolithic monuments, technology or agriculture before *c.* 5200 BP (4000 cal BC). In fact, the earliest direct ^{14}C age measurements on cultivated cereal remains are very similar to those from Scotland.

Dietary tracing of human bone

The measurement of stable isotope ratios in human skeletons is a useful tool for reconstructing ancient diets. Stable carbon isotope ($\delta^{13}\text{C}$) ratios, in particular, have been used to study the importance of marine foods in the economies of Mesolithic peoples inhabiting maritime regions of Europe and the changes associated with the spread of agriculture into those regions (*Tauber 1981; Price 1989; Lubell et al. 1994*). This is possible because (where C_4 plants are absent from the food chain) the $\delta^{13}\text{C}$ ratio of collagen extracted from human bone closely reflects the ratio of marine to terrestrial protein consumed by the individual (*Arneborg et al. 1999*).

Figure 3B summarizes the results of paired ^{14}C and $\delta^{13}\text{C}$ measurements on human bones from 10 sites in coastal areas of northern and western Scotland. These sites include caves, chambered cairns and shell middens, and the human remains range in age from *c.* 5400–4400 BP (4300–3000 cal BC).

A clear distinction is evident between the $\delta^{13}\text{C}$ profiles of individuals belonging to the periods before and after 5000 BP (3800 cal BC). Those individuals dated before 5000 BP (3800 cal BC) (represented by four samples from two sites on the island of Oronsay with (reservoir corrected) mean ^{14}C ages between 5335 BP and 5075 BP) have $\delta^{13}\text{C}$ ratios in the range -12‰ to -16‰ (*Richards and Mellars 1998; Richards and Sheridan 2000*). Assuming $\delta^{13}\text{C}$ values of -12.5‰ for a 100% marine diet and -21‰ for a 100% terrestrial diet (*cf. Arneborg et al. 1999*) the Oronsay data suggest a population that relied heavily on marine foods as the main source of protein. In contrast, those individuals dated after 5000 BP (3800 cal BC) (represented by 30 samples from 8 sites with mean ^{14}C ages between 4990 BP and 4410 BP) exhibit much lower $\delta^{13}\text{C}$ ratios ranging between -19.5‰ and -22.6‰ , indicating diets in which virtually all of the protein was of terrestrial origin.

Since there is no reason to suppose that the people whose remains were found in the Oronsay middens placed more emphasis on marine resources than their contemporaries elsewhere in western Scotland, the results from dietary tracing may be used to infer that a major shift in regional subsistence practices occurred between *c.* 5100–5000 BP (3950–3800 cal BC). Given that diagnostic elements of Neolithic material culture also appear in the archaeological record around that time, the simplest explanation of the change in dietary patterns is that it reflects the shift from an economy based on hunting and gathering to one based on farming.⁴

If this interpretation is correct, then it also contradicts the view expressed by several authors (*Thomas 1991; Armit and Finlayson 1992; Whittle 1999*) that 'wild' foods played a major role in the Early Neolithic economy. Otherwise, it would be necessary to argue that wild land mammals and plants assumed much greater economic importance in the Neolithic than they did during the Mesolithic.

4. Since the text of this paper was finalized, the authors have become aware of an article by Richards and Hedges (1999) which draws similar conclusions regarding changes in subsistence patterns across the Mesolithic-Neolithic transition in England and Wales based on C-isotope data. No alterations have been made to the present paper in light of the data or interpretations published by Richards and Hedges.

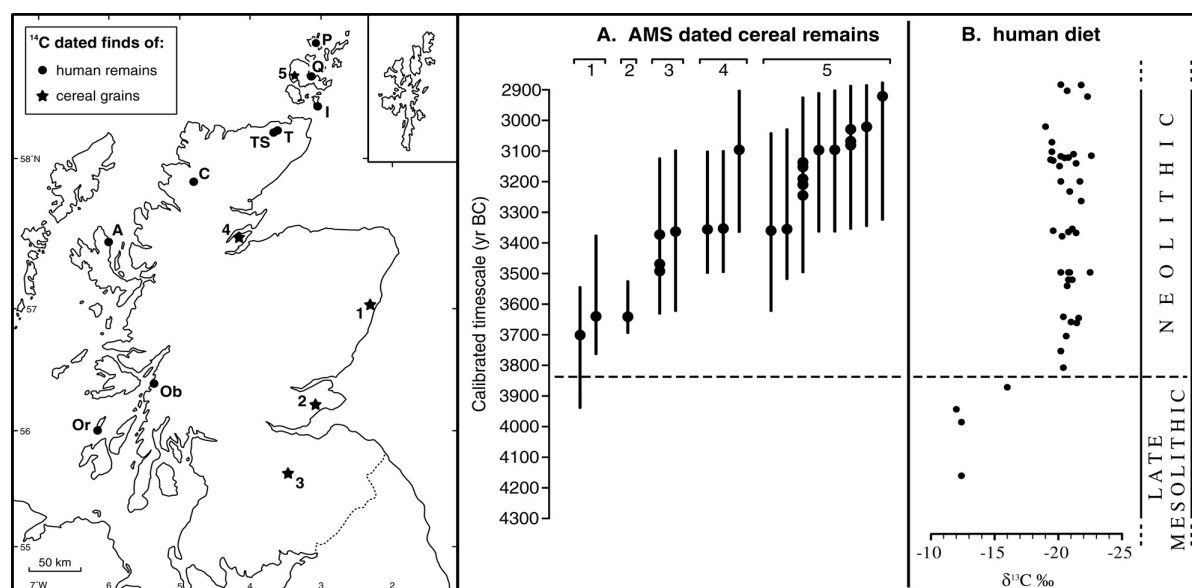


Fig. 3. Key indicators of economic change across the Mesolithic-Neolithic transition in Scotland. A – earliest radiocarbon dates (2-sigma age-ranges) for cultivated cereals: 1 – Balbridie (Aberdeenshire), 2 – Balfarg Riding School (Fife), 3 – Biggar Common (South Lanarkshire), 4 – Kinbeachie (Highland), 5 – Burnhouse (Stenness, Orkney). B – carbon stable isotope results from human skeletons dating between 4300 and 2900 cal BC: A – An Corran (Skye), C – Creag nan Uamh (Assynt), I – Isbister (Orkney), Ob – Oban (Argyll), Or – Oronsay (Argyll – 2 sites), P – Point of Cott (Orkney), Q – Quanterness (Orkney), T – Tulloch of Assery A (Highland), TS – Tulach an t'Sionnaich (Highland). The abrupt change in the $\delta^{13}\text{C}$ values c. 3850 cal BC indicates a shift in diet/subsistence patterns from mainly marine to mainly terrestrial. Data from various sources, including Bonsall (1999, unpublished), Bonsall and Murray (1998), Dalland (1999), Fairweather and Ralston (1993), Richards C. (1994), Richards M. and Sheridan (2000), Saville (1999) and Ward (1997).

The lack of marine protein in the diets of Early Neolithic peoples in western and northern Scotland is surprising, given the proximity of the sites to the sea. However, it is not without parallel elsewhere on the Atlantic seaboard of Britain. Similar evidence was reported from the Neolithic chambered cairn of Parc le Breos Cwm on the Gower peninsula of south Wales (Richards 1998). Richards (1998:166) speculated that the people buried in the tomb might have been high status individuals who had preferential access to terrestrial animal protein, such that their stable isotope profiles were unrepresentative of the local Early Neolithic population as a whole. This hypothesis would be more difficult to sustain for the Scottish sites since the human remains come not just from chambered cairns, but also from caves and shell middens – and in the case of the shell middens there is no certainty that the bones represent formal burials.

Palynological data

There has been much discussion in the archaeological and palynological literature of the significance of occasional finds of cereal-type pollen in peat sequences from Scotland and other parts of the British Isles

spanning the period from the 'elm decline' of c. 5100/5000 BP (3950/3800 cal BC) (at one time accepted as the definitive palynological marker of the beginning of the Neolithic) back to c. 5800 BP (4650 cal BC) (Edwards and Hiron 1984; Edwards 1989; Edwards and Whittington 1997).

Some workers have interpreted these 'early' cereal-type pollen occurrences as evidence for small-scale agriculture prior to the development of a 'full' Neolithic economy and culture. This in turn has helped to sustain the concept of a centuries-long 'pioneer phase' preceding the main (monument building) phase of the Neolithic during which it is envisaged that hunting and gathering was the main form of subsistence technology but with agriculture, practised initially by small, dispersed groups of indigenous hunter-gatherers or immigrant farmers, gradually increasing in importance.

This argument is unconvincing for three main reasons. First, cereal-type pollen can emanate from wild as well as cultivated grasses (*cf.* Edwards and Whittington 1997:72). Secondly, pre-elm decline cereal-type pollen is by no means confined to the period between 5800 and 5000 BP (4650 and 3800 cal BC).

It has been recorded from much earlier contexts, most notably in the Oban region of western Scotland where it was found in early Holocene deposits at several sites back as far as *c.* 9700 BP (9200 cal BC) (Macklin *et al.* 2000). Thirdly, although a number of sites in Scotland have produced cereal-type pollen grains from pre-elm decline deposits, there is no securely dated *macrofossil* evidence of cereal cultivation earlier than *c.* 5000 BP (3800 cal BC).

Although the mere presence of cereal-type pollen is inadequate evidence of agriculture, a change in the pattern of occurrence of cereal-type pollen grains supported by other palynological indicators may convincingly indicate the time when farming took over from hunting and gathering as the main economic system. This is well illustrated by the work of Macklin *et al.* in the Oban area (Macklin *et al.* 2000). In order to document the history of environmental change during the Holocene at both local and regional scales, a comparison was made of the pollen, micro-charcoal and geochemical records from five radiocarbon dated peat sequences along an altitudinal transect from *c.* 3 m O.D. near the present coast to *c.* 300 m O.D. 9 km inland. The results are summarized on Figure 4. Although there are very early occurrences of cereal-type pollen in several sites, there is no supporting evidence for agriculture or major human impact on the landscape prior to *c.* 5000 BP (3800 cal BC). The first convincing evidence for land clearance related to agriculture occurs around that time. For example, pollen analyses from Gallanach Beg and Lochan a'Builgh Bhith both show the first substantial increases in *Plantago* spp. (indicative of land clearance) at about 5000 BP (3800 cal BC). There is also evidence for reduction in arboreal pollen, increased charcoal deposition, and a marked rise in the frequency and quantity of cereal-type pollen. At Gallanach Beg these coincide with a significant increase in erosion rates probably in response to soils being tilled for the first time.

The Elm Decline

The first palynological evidence for agriculture in the Oban region also coincides with the well-known elm decline, which is found in pollen sequences throughout the British Isles and Scandinavia at *c.* 5000 BP (3800 cal BC).

At one time climate change was invoked as the primary cause (Iversen 1941; 1944). Then, following the work of Troels-Smith (1960) it was interpreted as a consequence of Early Neolithic people attempt-

ing to keep livestock in a landscape with (initially) very little grass vegetation, so that they resorted to the use of elm leaves as fodder. More recently, this idea has fallen out of favour and disease (associated with the elm bark beetle *Scolytus scolytus*) is now regarded as the most likely explanation of the elm decline (Girling and Greig 1985; Perry and Moore 1987; Girling 1988; Peglar 1993; Peglar and Birks 1993).

While at first sight the disease hypothesis appears to offer a satisfactory mechanism, closer inspection suggests that disease is unlikely to have acted in isolation. Although a large number of pollen diagrams show an elm decline at about 5000 BP (3800 cal BC) across north-west Europe, there has been little attempt to define the geographical range of this event in relation to the geographical range of elm at that time. Indeed, elm trees were an important component of mid-Holocene woodlands across much of France, Germany and northern Italy (Huntley 1988) – areas with little evidence for an elm decline *c.* 5000 BP (3800 cal BC). If disease were the primary cause, why should evidence for the elm decline be restricted to north-west Europe? More specifically, why should an outbreak of disease leave such strong evidence in the pollen record of southern England (*e.g.* Scaife 1988) while being virtually absent just across the channel in northern France? A more likely explanation is that evidence for the elm decline *c.* 5000 BP (3800 cal BC) is strongest in north-west Europe *because* this area was undergoing the Mesolithic-Neolithic transition while areas to the south and east had already gone through this transition around a thousand or more years earlier. In fact, a detailed palynological study in the Paris Basin (van Zeist and van der Spoel-Walvius 1980) shows no clear evidence of an elm decline *c.* 5000 BP (3800 cal BC). Instead, it shows strong evidence from two sites (Silly-la-Poterie and Chivres) for an elm decline at about 6000 BP (4900 cal BC), around the time of the adoption of agriculture in this region. A similar date for an early elm decline is also reported from a site in the central Netherlands (Hofstede *et al.* 1989) and attributed to Neolithic activity.

It is difficult to see the spatial and temporal similarities between the mid-Holocene elm decline and the Mesolithic-Neolithic transition in north-west Europe as merely coincidental, and it is highly plausible that human activity and disease worked together. It is known that *S. scolytus* is not favoured by dense forests, but thrives in more open habitats with isolated copses and single trees (Girling and Greig 1985),

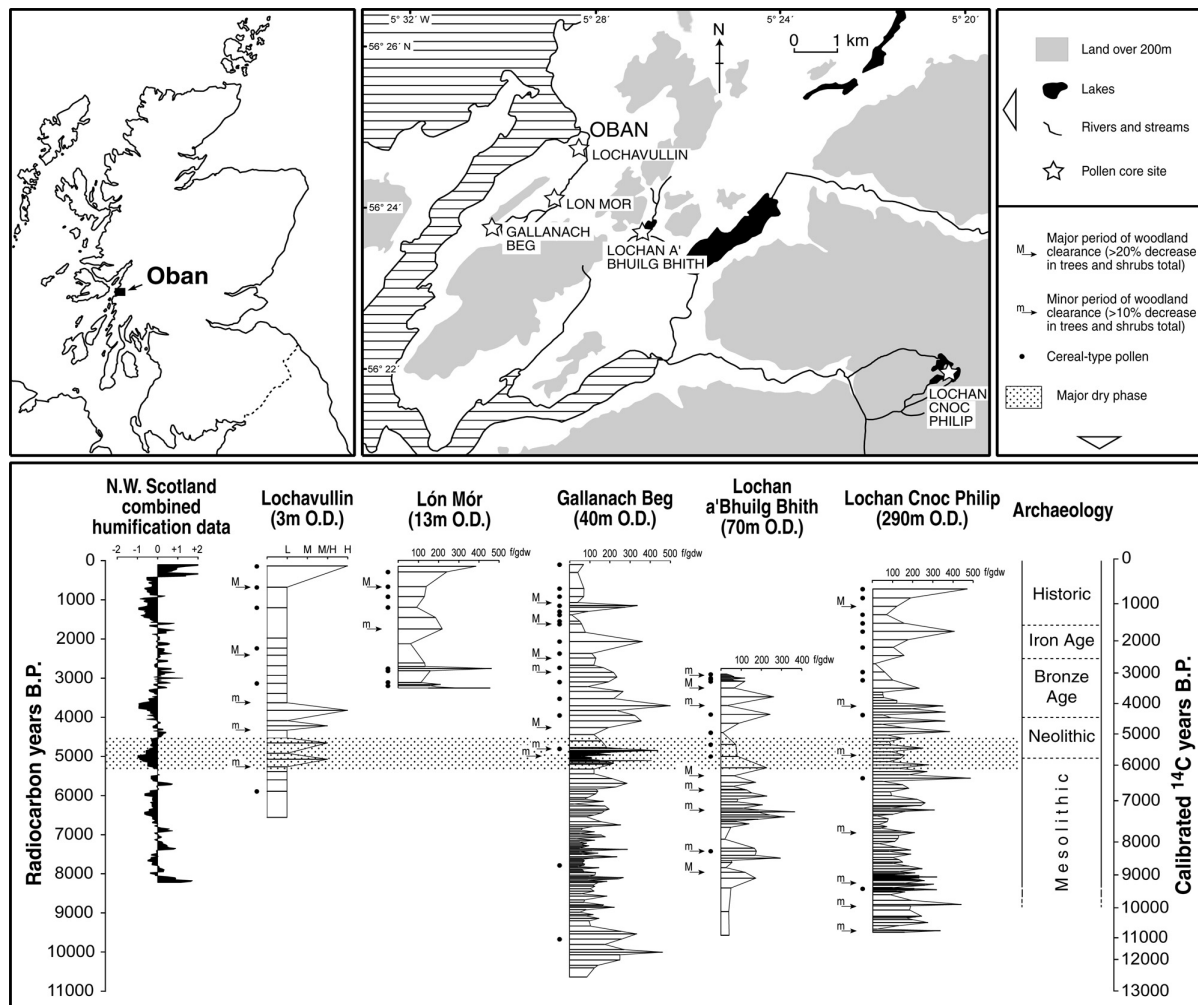


Fig. 4. Holocene climatic changes inferred from peat bogs in north-west Scotland (Anderson et al. 1998) plotted against the micro-charcoal, cereal-type pollen and woodland decline records from five sites in the Oban area along an altitudinal transect from coast to upland (adapted from Macklin et al. 2000). Time-ranges of Mesolithic and later settlement in the region, established from archaeological research, are also shown. The stippled zone marks the prolonged phase of relatively dry climate between c. 4100 cal BC and 3200 cal BC.

and hence early land clearance may have promoted the spread of the disease into new areas.

The main point that emerges from the foregoing discussion is that consideration of three separate lines of evidence – radiocarbon dating of archaeological finds, dietary tracing of human bone, and palynology – leads to the same broad conclusion. The transition from Mesolithic to Neolithic in western Scotland was a relatively short-lived and discrete event, occurring between 5300 and 5000 BP (4100–3800 cal BC) rather than a protracted process of gradual economic and cultural change beginning as early as 5800 BP (4650 cal BC) as envisaged by some researchers. The same was probably true of

areas outside Scotland, since there is no firm evidence for Neolithic culture and economy anywhere in the British Isles before 5300 BP (4100 cal BC).

WHY DID IT HAPPEN WHEN IT DID?⁵

It has long been recognized that there was a ‘delay’ of 800–1300 years in the adoption of agriculture in the British Isles and southern Scandinavia compared to neighbouring regions of continental Europe (Rowley-Conwy 1981; Kinnes 1984). Zvelebil and Rowley-Conwy (1986) argued for a similar delay in many areas on the Atlantic seaboard of Europe. They attributed this to the maritime focus of indigenous

5. Some of the ideas and interpretations presented in this section of the paper have since been refined and published elsewhere (Bonsall et al. 2002).

Mesolithic economies that provided the basis for productive and stable settlement-subsistence systems, allowing hunter-gatherers to 'resist' agriculture for a considerable time.

There are two problems with this hypothesis. First, as research has progressed, the date of the earliest Neolithic in many coastal areas of Europe (e.g. Portugal and north-west France) has been pushed back in time, so that it appears no longer valid to argue for a delay in the uptake of farming compared to areas inland. The only part of Europe where a marked delay is still evident is the British Isles and Scandinavia (Fig. 5). Secondly, it fails to explain *why* the Mesolithic inhabitants of this part of Europe (with their seemingly productive maritime economy) ultimately adopted farming. Rowley-Conwy (1984) attributed the eventual 'collapse' of the Mesolithic maritime system in southern Scandinavian and its replacement by farming at c. 5200/5000 BP (4000/3800 cal BC) to environmental stress. He argued that a shift to cooler, drier climatic conditions coincident with a sea-level related decrease in the salinity of the Baltic resulted in a sharp reduction in wild food resources, especially oysters which he believed had acted as a seasonal buffer against starvation.

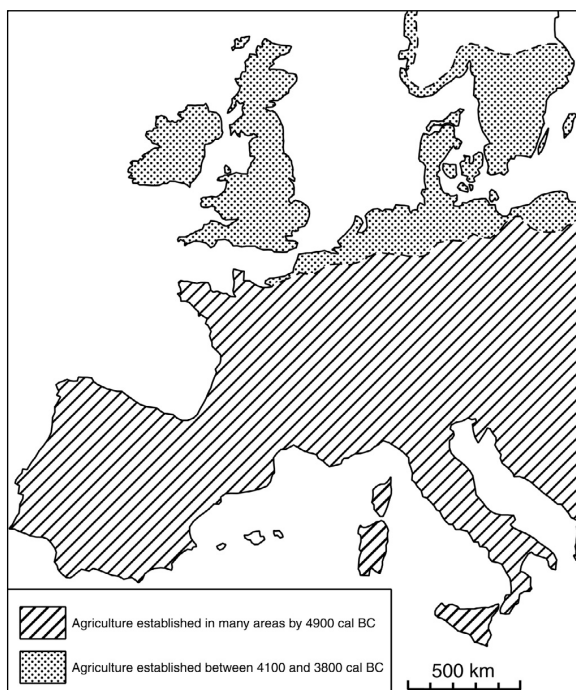


Fig. 5. Agricultural 'frontiers' in north-west Europe. Farming spread rapidly across the British Isles and southern Scandinavia between 4100 and 3800 cal BC, following a long period when the geographical limit of successful agriculture had remained more-or-less static on the North European Plain between northern France and northern Poland.

Rowley-Conwy's hypothesis has never gained wide acceptance among Scandinavian archaeologists, and cannot be applied outside the Baltic region. Nevertheless, despite the apparent deficiencies in Rowley-Conwy's hypothesis, it is still worth exploring the idea that climatic change was somehow a key factor in the transition from Mesolithic to Neolithic in north-west Europe. Until recently, it would have been almost impossible to do this in any detail because of a paucity of well-dated palaeoclimatic records spanning the mid-Holocene. However, recent advances in palaeoclimatology, especially in the analysis of peat stratigraphy, are helping to overcome this problem by providing regionally-based, continuous records of climate changes of sufficient temporal resolution.

Climate change in the mid-Holocene

Analyses of peat sequences from the Wester Ross area, north-west Scotland, have provided a detailed record of past changes in wetness and dryness back to c. 8250 BP (7250 cal BC) (Anderson 1996; 1998; Anderson *et al.* 1998). This reconstruction has involved humification, palaeoecological and radiocarbon analyses of peat cores from three different bogs (in Glen Torridon, Glen Carron and on Eilean Subhainn – an island in Loch Maree), each representing the palaeohydrology of a different drainage basin. The combined humification curve from these three peat bogs is shown on Figure 4.

The curve features several palaeohydrological shifts from 8000 BP (6950 cal BC) to the present. One of the major dry phases found in the record began c. 5300 BP (4100 cal BC) and culminated c. 5000 BP (3800 cal BC). This marked phase of relatively dry climate inferred from Wester Ross coincides with the first evidence for land clearance and agriculture further south along the west coast of Scotland in the Oban area (see above). The shift to drier conditions at c. 5300 BP (4100 cal BC) recorded in the Wester Ross peats may explain the timing of the adoption of agriculture along the west coast of Scotland.

Other peat-based studies in Scotland also indicate a phase of drier climate around this time. The combined humification curve from blanket peats on the slopes of Beinn Dearg, in northern Wester Ross (Binney 1997) shows a shift to drier conditions beginning c. 6250 cal BP and culminating c. 6000 cal BP (Anderson *et al.* 1998). Tipping (1995) also reports evidence for relatively dry conditions around 6000 cal BP from Burnfoothill Moss at Kirkpatrick Fleming, in southern Scotland.

Studies of lake sediments can also be used for inferring changes in climatic wetness or dryness. Of 28 lakes in Britain and Ireland evaluated by Yu and Harrison (1995a), a large proportion show relatively low lake levels between 7000 and 4500 BP (5850–3200 cal BC). More precise data are available from Achany Glen (northern Scotland), where the start of a prolonged hiatus in lake sediment accumulation (suggesting a phase of lower lake level) is dated to 5650±80 BP (GU-3951) (4690–4340 cal BC) (Smith 1996; Anderson *et al.* 1998).

The frequency of wood macrofossils preserved within peat can also be used as proxy evidence of climate change. Bridge *et al.* (1990) compiled radiocarbon dates for Scots pine stumps found in peats on Rannoch Moor (Scotland). They found distinct clusters of dates, especially at *c.* 6000 BP (4900 cal BC) and at *c.* 4500 BP (3200 cal BC), with an abundance of pine stumps indicating periods when conditions were good for wood preservation. Likewise, there are other periods of time that are under represented by pinewood, and Bridge *et al.* argued that these periods relate to phases of drier climate when preservation was poor due to more rapid decomposition. The most prominent trough in the frequency histogram of dated pine stumps is found at *c.* 5300 BP (4100 cal BC), closely matching the shift to drier conditions inferred from the Wester Ross peat sequences. Furthermore, Baillie (1992) reported a paucity of preserved oak wood in Irish peats between 4023 and 3916 cal BC. The lack of oak wood during this period may also relate to drier peat forming conditions associated with higher rates of decomposition. This phase of reduced oak is also matched by reduced frequencies of Irish pinewood (Baillie and Brown 1999).

Temperature reconstructions have been attempted from Holocene deposits using insect remains (Osborne 1982; Dinnin 1997). For instance, analysis of the beetle fauna from peat surrounding the Early Neolithic Sweet Track (Somerset Levels) suggests that climatic conditions were more continental than today at the time the structure was built *c.* 5000 BP (3800 cal BC) (Girling 1979; 1984).

Two beetle species associated with the Sweet Track are *Oodes gracilis* and *Chlaenius sulcicollis*. Today the northward limit of their distribution follows the 17°C mean July isotherm, and they are found in areas of Europe with a wide annual temperature range. For comparison, the winters in the Somerset Levels today are mild, averaging about 4 to 7°C, and

mean summer temperatures rarely exceed 16°C. In contrast, during the Early Neolithic, the beetle evidence indicates that mean summer temperatures in the Somerset Levels may have been 1 to 2°C warmer with an annual temperature range similar to that currently found in eastern Denmark (Girling 1984).

Climatic change at around 5000 BP (3800 cal BC) was not restricted to the British Isles. Indeed, various lines of proxy evidence suggest that a change in climate at this time also affected much of northern Europe. Peat stratigraphic evidence from the Meerstalbog bog in the Netherlands shows a distinct shift to drier conditions estimated at *c.* 6000 cal BP (Dupont 1986). Furthermore, lake levels throughout north-west Europe were generally low at 5000 BP (3800 cal BC) (Yu and Harrison 1995b), and a detailed study from Lake Bysjön, southern Sweden, showed a lake level regression from *c.* 5300 BP (4100 cal BC) to *c.* 4700 BP (3450 cal BC) (Digerfeldt 1988). Evidence for temperature change can be gleaned from studies of Scots pine tree-ring widths, and one such temperature reconstruction by Briffa (1994) shows that mean July/August temperatures in northern Fennoscandia increased by about 1°C at 5200 BP (4000 cal BC). This is also consistent with evidence for an increase in the altitudinal limit of Scots pine in Scandinavia dated to 4000 cal BC (Karlen and Kuylenstierna 1996). A temperature reconstruction based on speleothem data from northern Norway places the temperature rise (of approximately 1°C) a little earlier, at *c.* 4400 cal BC (Lauritzen and Lundberg 1999).

Chemical analyses of the Greenland GISP2 ice core show several shifts in the amount of sea salt incorporated within the ice layers spanning the Holocene. O'Brien *et al.* (1995) argued that phases of higher sea salt concentration within the ice core indicate times when a more meridional atmospheric circulation pattern prevailed in the North Atlantic. One of the most prominent increases in sea salt concentration occurred at *c.* 6000 cal BP, closely matching the shift toward drier climatic conditions and warmer summers in north-west Europe. A shift to a more meridional circulation would have caused warmer summers and colder winters. When the upper westerly airflow is relatively zonal, moisture-laden air masses frequently track across northern Europe throughout the year, moderating seasonal swings. However, a more meridional air flow over the North Atlantic favours more frequent periods of blocking high pressure. In the summer this brings clear skies and higher temperatures whereas in the winter, more fre-

quent high pressure is associated with colder and drier conditions.

Summing up climatic change c. 5000 BP (3800 cal BC)

The idea of significant climatic change in northern Europe at around 5000 BP (3800 cal BC) is not new. Indeed, 5000 BP (3800 cal BC) has traditionally been thought to mark the transition from Atlantic to Sub-Boreal conditions as originally envisioned in the Blytt-Sernander scheme of post-glacial climatic change (*Mangerud et al. 1974*). It also marks the transition between zones VIIa and VIIb of the Jessen-Godwin pollen zonation scheme (*Godwin 1975*). On the basis of descriptive peat stratigraphy in Scandinavia, Blytt, and later Sernander, argued that a relatively wet Atlantic was followed by a drier Sub-Boreal period (*Sernander 1908*). Later work by Iversen (*1941; 1944*) on the pollen of spectra from deposits in Denmark showed a decline in the pollen of thermophilous taxa, notably ivy, holly and mistletoe, associated with the European elm decline (c. 5100 BP) (3950 cal BC). Iversen inferred a temperature decline from his data, and ever since, climate change at 5000 BP (3800 cal BC) has often been seen as a climatic deterioration, with the onset of the Sub-Boreal bringing colder and more continental conditions. 'Climatic deterioration' has been supported by more recent studies, including some reconstructions of alpine glacier advances that show an expansion of glaciers in mountainous regions of Europe at, or shortly after, 5000 BP (3800 cal BC) (e.g. *Denton and Karlén 1973; Nesje et al. 1991; Nesje and Johannessen 1992*). In fact, O'Brien *et al.* (1995) also interpret their shift towards increased sea salt in the GISP2 core at 5200 BP (4000 cal BC) as representing a phase of climatic deterioration that correlates with glacial advances world-wide. However, pinning down the timing, and the causes, for alpine glacial advances is by no means straightforward, and some reconstructions actually show glacial retreat around 5000 BP (3800 cal BC), notably in Scandinavia (*Röthlisberger 1986*).

At first glance, it may seem that this older view of climatic change at around 5000 BP (3800 cal BC) is at odds with the more recent evidence for drier conditions, with warmer summers, presented above. However, if the change is seen primarily as an increase in continentality, then new evidence can be squared with old. For instance, increased continentality, involving colder winters and warmer summers, can explain the decline in frost-sensitive forest

plants, as observed by Iversen, while also explaining the expansion of pine – a tree that would be less affected by severe winters and favoured by a warmer growing season. In the more mild, oceanic areas of north-west Europe, especially in north-west Scotland, temperature changes probably would have been less significant than changes in moisture, and hence the climatic change around 5000 BP (3800 cal BC) is most easily detected in palaeohydrological archives such as peat bogs.

Climatic change and the adoption of agriculture in north-west Europe: a working hypothesis

Climate is a critical factor affecting the viability of all agricultural systems, and the Early Neolithic system of mixed cereal cultivation and livestock husbandry would have been no exception. In fact, it may have been especially sensitive to relatively small changes in precipitation or temperature given the limitations of early farming technology and because pioneer farmers would not have had the benefit of hindsight when dealing with marginal conditions or periods of environmental stress. As discussed previously, cereals were a crucial component, vital as a storable source of winter food for both humans and livestock. Cereals can be grown under a wide range of environmental conditions, although the yield will vary with climate, soils and other factors. In north-west Europe, an important control of cereal yields would have been the length of time that soils were waterlogged during winter. The incidence of waterlogging depends not only on precipitation levels, but also on the structural properties of the soil. There is a much greater tendency to seasonal waterlogging in soils with slowly permeable clayey subsoils, as well as in low-lying situations where there is a high groundwater table (e.g. estuaries and inland basins). Waterlogging can adversely affect cereal yields in several ways. It will inhibit germination and retard growth in cereals and other crops. It also affects the 'workability' of the soil. When saturated the soil is unsuitable for cultivation because of stickiness and plasticity, and such conditions preclude autumn sowing of cereals or delay planting in spring thereby reducing the length of the growing season. A shift to a more continental-type climate at, or shortly after, 5300 BP (4100 cal BC) with lower winter precipitation and, less critically, higher summer temperatures would have enhanced the prospects for successful cereal cultivation. This effect would have been most pronounced in the more maritime areas where precipitation levels tend to be higher, as well as on fine-textured, poorly drained soils.

If the 'neolithization' model applies, and indigenous Mesolithic people were largely responsible for the spread of agriculture across the British Isles and southern Scandinavia, then it is reasonable to assume that farming would have developed first in areas they already occupied. There is strong evidence that in the final stages of the north-west European Mesolithic most people inhabited the coastal zone. Today, the coastal areas of north-west Europe have high winter precipitation and/or extensive tracts of slowly permeable poorly drained soils derived from glacial or raised estuarine/marine deposits. For cereal agriculture to be adopted widely in these areas such soils would have to be taken into cultivation.

Under these climatic and edaphic conditions, the shift to a more continental-type climate beginning *c.* 5300 BP (4100 cal BC) would have represented an 'improvement' with respect to cereal cultivation. It is possible, therefore, that the change in climatic conditions facilitated the uptake of agriculture by indigenous hunter-gatherers in the British Isles and southern Scandinavia by increasing cereal yields and thereby improving the agricultural potential of large areas especially at the coastal margins. By extension this hypothesis provides an underlying mechanism to account for the relatively sudden appearance of the Neolithic throughout this region between 5200 and 5000 BP (4000 and 3800 cal BC).

The corollary of this model is that very probably climatic conditions were both the cause of the 800–1300 year 'delay' in the spread of agriculture from the North European Plain and northern France into southern Scandinavia and the British Isles, as well as the major stimulus of its eventual adoption in those regions. When agriculture became established on the North European Plain and along the Channel coast in the centuries around 6000 BP (4900 cal BC) (Fig. 5), prevailing climatic and technological conditions may have been such that the Neolithic farming system had reached the geographical limit of its viability, with areas to the north and west at that time being marginal for agriculture. It was not until the climatic 'improvement' of *c.* 5300–4500 BP (4100–3200 cal BC) that further expansion was possible, allowing cereal cultivation and animal husbandry to become widely established in the British Isles and southern Scandinavia for the first time. However, once established and adjusted to local conditions, the Neolithic farming system was likely to cope with subsequent climatic reversals even if this necessitated the temporary abandonment of agriculturally marginal areas (*cf. Champion 1999*).

This hypothesis, however, does *not* rule out the possibility of earlier attempts at farming in the British Isles and southern Scandinavia prior to 5300 BP (4100 cal BC). Indeed, it is possible to envisage situations in which there *were* experiments with agriculture, but on a scale and duration that would be difficult to detect in the archaeological and palynological records.

The explanatory model of the Mesolithic-Neolithic transition in north-west Europe presented above may have relevance for other regions, especially upland areas such as the Alps, Carpathians and Cantabrian mountains, where climate change during the early Holocene could have created similar windows of opportunity allowing the adoption or expansion of farming into formerly marginal environments.

CONCLUSIONS

This study of the Mesolithic-Neolithic transition in Scotland within the wider north-west European context has reached four principal conclusions:

- ❶ The transition from Mesolithic to Neolithic in Scotland (and throughout the British Isles) was a relatively short-lived and discrete event, occurring sometime between 5300–5000 BP (4100–3800 cal BC) – and not the protracted process of gradual economic and cultural change beginning over half a millennium earlier that some researchers have envisaged.
- ❷ Native Mesolithic peoples probably played a significant if not dominant role in the development of Neolithic culture and economy in the British Isles, although on present evidence the possibility that immigrant farmers were also involved cannot be excluded.
- ❸ The rapidity with which agriculture, once adopted, was able to spread across the British Isles and other maritime areas of Europe was due in part to the availability of animal domesticates that would have provided native hunter-gatherers with new opportunities for the acquisition of wealth and power, as well as alternative sources of food and raw materials.
- ❹ The widespread adoption of farming across the British Isles and southern Scandinavia between 5300–5000 BP (4100–3800 cal BC) following a long interval when the agricultural frontier lay further south in continental Europe, coincided with a shift to a more continental-type climate with lower winter precipitation and, perhaps, higher summer temperatures. By improving the prospects for cereal cultivation on land that previously was marginal for agri-

culture, this climatic event may have been a key factor in the transition from Mesolithic to Neolithic in north-west Europe.

Some of the arguments advanced in support of these conclusions reinforce views expressed by previous authors, by bringing new evidence to bear. Others are original and for that reason may be regarded as contentious, not least the suggestion of a causal link between climate change and the expansion of the Neolithic across north-west Europe. Much remains to be learned about climatic conditions during the mid-Holocene at local, regional and sub-continental scales, as well as the effects of relatively minor changes in precipitation and temperature on prehistoric land use patterns. This is an obvious priority area for fu-

ture research. If this paper helps in some small way to stimulate that research, it will have served its purpose.

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