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Moments of crisis: climate change in Scottish prehistory

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ABSTRACT

There is strong evidence for many key turning points in Scottish and north-west European prehistory – what we call moments of 'crisis' – to be associated with evidence for widespread and abrupt natural changes in climate. Association or coincidence are not cause, though, and the testing of specific hypotheses to establish this relation is needed. The timing of these moments of abrupt climatic change in Scottish prehistory is proposed in a review of the many new data-sets of prehistoric climate change affecting the North Atlantic region. The case is made that Scotland in prehistory, because of its location in the North Atlantic region, should become a testing-ground of the relation between prehistoric society and climate change, to move debate beyond merely coincidence matching.

INTRODUCTION

There has been a paradigm shift in how we understand the scales and rates of natural climate change in the present interglacial, the Holocene Epoch, spanning the last *c* 11,700 years (Chambers & Brain 2002). The old paradigm of slow, gradual change (Lamb 1977, 1995) has been replaced by one in which change can be described as abrupt, occurring over short timescales of centuries or less, separated by comparatively long periods of quasi-stasis (Mayewski et al 2004). The coincidence in timing of these hemispheric-scale abrupt climate changes (eg Barber et al 2000; Mayewski et al 2004; Wanner et al 2008; Charman 2010) to major transformations in prehistoric societies and economies in north-west Europe is now hard to ignore (Berglund 2003; Turney et al (2005); Karlen & Larsson 2007). The scales of natural climatic change appear to be potentially large enough to have impacted on human societies (de Menocal 2001; Mitchell 2008). Whether or not they did needs to be rigorously tested.

This paper argues that there is now a pressing need to move beyond the recognition of coincidence in climatic and archaeological records to the careful construction of testable hypotheses to explain the relation between past societies in Scotland and natural climate change. Scotland, through its location in the north-east Atlantic Ocean, is critical to understanding this relation as terrestrial climate is strongly modulated by changes in atmospheric and marine circulation (Debret et al 2009). There has been considerable discussion of this issue in northern Britain (eg Piggott 1972; Parry

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1975; Burgess 1980, 1985; Barber 1998; Tipping 2002) but much needs to be resolved. Reshaping the debate is urgently needed. We need to understand how communities perceived events like rapid climate change by exploring how people saw their place in nature, and how they perceived risk and acquired resilience. We need to define the choices open to communities at times of crisis: recognising choice provides the riposte to environmental determinism (Thomas 1991; Coombes & Barber 2005). How did societies make decisions at these times? Who made decisions? Did communities draw on past experience and how were these experiences remembered? What was the role of social memory and myth? What decisions were made? What were the preferred strategies? We need to assess in hindsight the success of these decisions. Was crisis the spur to innovation or did it lead to conservatism? We need to understand crisis in terms of coping and resilience more than defeat and abandonment. We also need to quantify and define the parameters of the environmental stresses confronted by communities and explore their complexities and feedbacks.

This contribution might serve as the first step in a sustained discourse between archaeological and palaeoenvironmental research communities in and working in Scotland. The aims of this paper are limited. It focuses primarily on the evidence for climatic change that impacted on people in prehistory, and presents a literature that is possibly unfamiliar to archaeologists. There is little detailed discussion of the archaeological record in Scotland. Rather, we use a recent interpretation of archaeological change in the British Isles (Bradley 2007) to explore periods of societal change. We do not relate any of these turning-points as specifically climatic in causation: we cannot yet do this with confidence. We argue that, at present, the archaeological and palaeoclimatic records in Scotland are inadequate to allow this, but in a final section we suggest ways forward.

THE COURSE OF PREHISTORIC CLIMATE CHANGE RELEVANT TO SCOTLAND

This section summarises what we think we know about changing climate in north-west Europe in prehistory. The overwhelming bulk of the data originates outwith Scotland but these data-sets will also reflect – to some degree – climatic change in Scotland. There are limitations in all data-sets. They are, of course, proxy records and we have to assume they record what we think they do. Sometimes this has proved incorrect. For example, isotope analysis of Scots pine trees in the Cairngorm (Dubois & Ferguson 1985, 1988) was argued to be a proxy for precipitation change (Dubois 1984) but it is more likely to reflect temperature change (van Geel & Middeldorp 1986). Some archives are good at defining short-term climate change and some at identifying the longer rhythms of glacial-interglacial climatic cycles, so not all fluctuations will appear in all data. Some data are ambiguous as to their meaning. For example, changes through time in the depth of the water table in raised mosses may relate to changes in precipitation or to changes in evapo-transpiration. The same type of data can be interpreted in radically different ways: McDermott et al (2001) interpreted a record of climate change from stalactites in western Ireland in terms of temperature, whereas a comparable record from a cave near Inchnadamph in north-west Scotland is interpreted in terms of precipitation (Charman et al 2001; Proctor et al 2002). Climate change is often discussed only in relative terms (eg wetter than …, warmer than …) though quantification is improving rapidly. Proxy data on absolute changes in, for example, temperature or precipitation often have large statistical errors, resulting in imprecision. At present, such weaknesses restrict the ability to define specific climatic stresses that can be predicted to have led to resource depletion or loss. Just now, there are comparatively few data-sets. Because there is scarcity of data in

Scotland itself, there is a danger in making inappropriate correlations with data too distant from Scotland. Data on several key climatic variables, which would have had great significance to past farming communities (such as seasonality: Davis et al 2003), are as yet few. These points should be borne in mind in what follows.

The Younger Dryas Stadial succeeded to the Holocene Epoch at around 9700 BC. In Greenland, this occurred in a matter of decades only, with the main changes taking less than 10 years (Taylor et al 1993; Alley 2000). The early Holocene climatic amelioration was interrupted by a series of abrupt hemispheric or global climatic events. The establishment of *Betula* (birch) woodland in the Netherlands from *c* 9550 BC (Friesland Phase) was interrupted around *c* 9400 BC by a dry, continental climate, the Rammelbeek Phase, correlated with the Preboreal Oscillation in the NGRIP record. Effective precipitation increased after *c* 9250 BC (Bos et al 2007) with the re-establishment of the oceanic North Atlantic Current redistributing heat poleward (Andresen et al 2007). Dense woodland was established in the Netherlands at *c* 8730 BC (Bos et al 2007). Further short-lived deteriorations in climate occurred at *c* 8350 and *c* 7550 BC (Hoek & Bos 2007), and *c* 7350 BC.

The major early Holocene climatic reversal at *c* 6200 BC (known as the 8.2 ka BP event) (Alley et al 1997; Alley & Agustdottir 2005) was small in comparison with Lateglacial oscillations but had widespread, hemispheric impacts and involved a temperature depression of 2–3ºC (Klitgaard-Kristensen et al 1998), felt most strongly at the latitude of Scotland (Seppä et al 2007). North-west Europe, including Scotland, was, in addition, markedly more arid. Stager & Mayewski (1997) and Debret et al (2009) argued that northern hemispheric atmospheric circulation before *c* 6200 BC was different to today because of the persistence of an ice-sheet until this time over the northern American continent: recognisable 'Holocene' climatic patterns may have commenced only after this time.

No significant climatic reversals are recorded in north-west European proxies from *c* 6200 BC until *c* 5000 BC. The period 5400 to 4500 BC was probably 1–2ºC warmer than the century prior to *c* AD 1950 in north-west Europe (Davis et al 2003). Temperature fluctuations within the Neolithic period are from this warm 'baseline'. The northern hemisphere cooled from *c* 4500 BC for some 400 years (Karlen & Larsson 2007), possibly principally felt in lower winter temperatures (Davis et al 2003). Soils became wetter from around 5050 BC, more so after *c* 4750 BC (Hughes et al 2000; Nesje et al 2001; Spurk et al 2002; Langdon et al 2003; Blaauw et al 2004; Magny 2004).

Large 'armadas' of icebergs drifted south from the Arctic Ocean at *c* 4700 BC (Moros et al 2004). This event is dated in ocean sediments west of Ireland at *c* 4350 BC (Bond et al 1997). The age differences reflect the limited temporal precision in slowly accumulating marine sediment. A probable response to a cooler North Atlantic Ocean is seen in lowered sea-surface temperatures in the southern Irish Sea and to the west of Ireland (Keigwin & Boyle 2000; Scourse et al 2002; Marret et al 2004), possibly triggered by weakening thermohaline circulation (Oppo et al 2003; Thornalley et al 2009). Thermohaline circulation in this context is the Atlantic Ocean 'pump' that moves warm water northward: weakening it would probably lower temperatures on land and in the sea. A concurrent increase in the frequency and intensity of westerly meridional (west–east) winds by 4450–4400 BC led to greater storminess around the North Atlantic Ocean, seen in sand-sheet/dune-building around the North Atlantic Ocean (Noren et al 2002; Wilson et al 2004; Jackson et al 2005), most noticeably after 4000–3800 BC (Keatinge & Dickson 1979; Gilbertson et al 1999; Bjorck & Clemmensen 2004; de Jong et al 2006; Melton 2008, 2009).

By 4350 BC, soils were drier (Hughes et al 2000; Nesje et al 2001; Spurk et al 2002;

Langdon et al 2003; Kalis et al 2003; Blaauw et al 2004). A *c* 2ºC fall in mean July air temperatures at 4200 BC is recognised in northern Scandinavia (Grudd et al 2002; Helama et al 2002), though a long way north of Scotland: work is ongoing to fill this void in Scotland (Wilson et al 2011). This fall might have lowered evapotranspiration rates, leading after *c* 4100 BC to wetter ground conditions. Temperatures ameliorated after *c* 4100–4000 BC (Cheddadi et al 1997; Grudd et al 2002; Karlen & Larsson 2007). Relative aridity intensified after 3800 BC (Hughes et al 2000; Nesje et al 2001; Spurk et al 2002; Langdon et al 2003; Blaauw et al 2004) as north-west European air temperatures became very warm (Karlen & Larsson 2007). A fall in air temperatures in northern Scandinavia at 3700 BC, with a much steeper fall at 3650 BC (Grudd et al 2002; Helama et al 2002), is associated with wetter soils after *c* 3650 BC. Dune building re-occurred at *c* 3950–3700 BC (Gilbertson et al 1999; Bjorck & Clemmensen 2004). Atmospheric circulation in the North Atlantic weakened by *c* 3400 BC (Bond et al 1997; Bond et al 2001) and became stable for a few centuries.

Around 3200–3100 BC there was a cluster of dune-building events on Irish coasts facing the northern Atlantic, suggesting a return to stormy conditions (Caseldine et al 2005; de Jong et al 2006; Holmes et al 2007). Summer temperatures in northern Scandinavia continued to fluctuate, falling at 3200 BC and recovering at 2900 BC (Grudd et al 2002), after which it became very warm (Karlen & Larsson 2007). Moir et al (2010) suggest that dryer soils encouraged the growth of *Pinus* trees, growing on blanket peat in northern Scotland between 3200 and 3000 BC. Wetter soils stunted growth from 3000 BC. Major climatic excursions in the later Neolithic to *c* 2200 BC appear fewer, save for wetter soils after *c* 2500 BC and an increase in dune-building between *c* 2800 and *c* 2400 BC (de Jong et al 2009) and after *c* 2300 BC (Karlen & Larsson 2007).

The period 2500–2200 BC was substantially wetter than average (Barber et al 1994; Anderson 1998; Anderson et al 1998; Tisdall 2000; Charman et al 2006). Soil water tables in central and southern Scotland (data are few farther north) were high at *c* 2000 BC, becoming lower by *c* 1500 BC, but rising to peak at 1400–1300 BC (cf Marret et al 2004). Lower soil water tables and dryer conditions were then sustained until *c* 800 BC (Charman et al 2006), though becoming markedly dryer after *c* 1150 BC (Swindles et al 2010). Although some distance from Scotland, Amesbury et al (2008) report evidence in south-west England for a wetter climate from *c* 1400 to *c* 1150 BC.

At *c* 2200 BC, there is a modest peak in ice-rafted sediment (Bond et al 1997; Bond et al 2001), cooling the North Atlantic Ocean, though it is unlikely that this event had a major impact on the strength of the 'gulf stream' (Oppo et al 2003). A substantial change in the stratification of the southern Irish Sea after *c* 1600 BC is explained by Marret et al (2004) as reflecting a strengthening of the 'gulf stream', leading to milder winters, possibly increased winter precipitation and reduced seasonal contrasts. Davis et al (2003) suggest for the region, including Scotland, that summer temperatures were warmer by around 1ºC at *c* 2000 BC, with winters around 1ºC colder. Seasonal contrasts appear, from palynological data, to have been reduced through the Bronze Age, with an 'oceanic' rather than a 'continental' climate. In northern Fennoscandia, summers in general warmed by 0.5ºC between *c* 2000 and *c* 1000 BC. At centennial resolutions, colder than normal centuries were rare after *c* 2000 BC, only the 15th century BC ranking as one of the coldest in the record. The 12th century BC was unusually warm (Helama et al 2002). The Crag Cave climate record in western Ireland (McDermott et al 2001) suggests, however, that mean annual temperatures were, in general, colder than the Holocene average throughout the Bronze Age, as cold as the later Neolithic, but warmer than the early Iron Age.

Early Bronze Age dune construction is recorded on the North Sea coast in northern

England (Wilson et al 2001; Orford et al 2000). Peaks in aeolian sand transport in southern Sweden were at *c* 2200–2100 BC, and then between *c* 1050 and 850 BC (Bjorck & Clemmensen 2004), the last at least relating to dry soils and possibly drought conditions in Northern Ireland (Swindles et al 2010). Machair on the Outer Hebrides was frequently mobilised between *c* 1800 and 1300 BC (Gilbertson et al 1999). Dune instability characterised the northern Irish coast after *c* 1400 BC and before *c* 1200 BC (Wilson et al 2004).

The Iron Age is taken here to mean the period between *c* 800 BC and *c* AD 50. Summer temperatures in Scotland were slightly warmer and winter temperatures not dissimilar to today (Davis et al 2003). Bond et al's (1997) record of ice-rafted sediment has a peak centred on *c* 800 BC. Oppo et al (2003) report ice-bearing surface ocean water off western Ireland between *c* 1100 and *c* 400 BC, the only time this occurred in the last *c* 5,000 years, because the 'gulf stream' was weakened. Wilson et al (2004) reported dune building and storminess *c* 1100–450 BC – as did Bjorck and Clemmensen (2004) in Denmark – but increased storminess is also recognised in several case studies after *c* 500 BC (Wilson et al 2001; Wilson 2002; de Jong et al 2009), and in the Outer Hebrides after AD 200 (Gilbertson et al 1999).

McDermott et al's (2001) speleothem record from western Ireland describes rising mean annual temperatures from *c* 1200 BC, stable and with limited variability around 800 BC, followed by increased variability but falling temperatures to *c* 400 BC. Oscillations were then extreme until *c* 200 BC, after which there were highly variable but falling temperatures to *c* AD 400. A different way to understand such changes is provided by Swindles et al's (2010) records in Antrim, from peat-based measures of drought (summer water deficit), with three phases, *c* 1150 to *c* 800 BC, *c* 320 BC to *c* AD 150 and *c* AD 250 to *c* AD 470.

A stalactite-derived climate record in Inchadamph is interpreted to depict annual precipitation more than temperature (Proctor et al 2002). Declining precipitation between *c* 900 and *c* 700 BC fits well with warm and dry indications in Irish sequences. Much higher precipitation is seen from *c* 700 BC to *c* 300 BC. Drought in northern Ireland *c* 320 BC to *c* AD 150 is matched with dry conditions in northern Scotland, persisting beyond *c* AD 500, but lower temperatures would then have reduced the risk of drought. Temperature and precipitation are more difficult to separate in the peat-based effective precipitation records across northern Britain, synthesised by Charman et al (2006), but the period *c* 900 to *c* 750 BC was the driest in the later Holocene record. There was an abrupt shift at *c* 750 BC to very much wetter peat bog surfaces, and though drier over some 50 years around 400 BC, wet conditions were maintained until *c* 40 BC. Bog surfaces did not become dry until after *c* AD 200.

TIMES OF CRISIS IN PREHISTORIC SOCIETIES IN SCOTLAND

It is not the intention here to analyse the prehistorical archaeological evidence in Scotland in any detail: the scheme below is set out fully in Bradley (2007).

1. *c* 4000/3900 cal BC to *c* 3600 cal BC, with the introduction of agriculture and Neolithic ideas (Sheridan 2010; Bayliss et al 2011; Garrow & Sturt 2011)
2. *c* 3600 to *c* 3300 cal BC, towards the end of the early Neolithic when the archaeological record suggests that the expansion of settlement faltered and people became less inclined to a sedentary life (Dark & Gent 2001; Brophy 2006; Bradley 2008)
3. *c* 3300 to *c* 3000 cal BC, when the first stone circles and large round barrows were erected (Gibson & Bayliss 2010; Gibson 2010, 64–73; Burrow 2010a & b)

4. *c* 3000/2900 to *c* 2700 cal BC, with the appearance of large palisaded enclosures and the adoption of Grooved Ware ceramics (Cleal 1999; Noble & Brophy 2011)
5. *c* 2700 to *c* 2400 cal BC, with the construction of the largest henge monuments, timber circles and stone circles (Gibson 2005; Parker Pearson 2012: ch 20 & 21)
6. *c* 2400 to *c* 2000 cal BC, and the occurrence of the first metalwork and Beaker pottery (Needham 2012; Sheridan 2012)
7. *c* 2000 to *c* 1600 cal BC, when there was a marked colonisation of upland areas (Ashmore 2001; Cowie & Shepherd 2003; Bradley 2007, 168–77). Little archaeological evidence for change is seen in Scotland between *c* 1600 and c.1100 cal BC
8. *c* 1100 to *c* 800 cal BC, as expansion was sustained, and open and enclosed settlement types appeared. This phase sees the use of the first hillforts and large hilltop settlements in northern and western Britain and in Ireland (Bradley 2007: 202–22).
9. *c* 800 to *c* 500 cal BC, a period in the British Isles when the rate of expansion slowed or halted and there was a significant hiatus in settlement evidence in Ireland (Needham 2007; Ralston & Ashmore 2007; Becker 2009)
10. *c* 500 cal BC to *c* cal AD 50, renewed expansion, and greater diversity in settlement types, in all regions of Britain (Cunliffe 2005: ch 9; Harding 2004: ch 2–5; Ralston & Ashmore 2007).

Analysing societal change from archaeological data is difficult. There are difficulties of spatial scale in, for example, relating site-specific sequences to a larger region, and of temporal scale in defining chronology from a limited number of well-dated examples. The 'three-age' model of prehistoric change reflects technological and not necessarily societal change, and such changes need not reflect major societal dislocations. The chronology above suggests constant change rather than a prehistory of rapid, abrupt dislocations followed by longer periods of stasis or dynamic equilibrium. This is partly due to the inevitable 'fuzziness' of using ^{14}C assays in defining boundaries. It is also an effect created by the archaeological record with its incomplete capture of data, biases in what is preserved, and in the way the record is compiled, from lots of individual points isolated in space and time because we have so few sites with long 'lifespans'. The problem remains, how to interpret the gaps in time between the scatter of points: continuity is perhaps best analysed from palaeoecological data (see below). But the 'fuzziness' may also be real, reflecting, for example, the rate at which innovation spreads within a population. But it is possible to isolate some phases as *crises*: *c* 3600 to *c* 3300 cal BC; *c* 3000/2900 to *c* 2700 cal BC; *c* 850 to *c* 500 cal BC.

TOWARDS A RESEARCH AGENDA

Globally, Scotland is exceptionally well-placed to fully explore the relation between people and climate change in prehistory. Its location in the north-eastern Atlantic Ocean, close to and connected with the oceanic thermohaline circulation system, makes it very sensitive to climate change. Large parts of Scotland have, for a long time, been seen as climatically marginal for farming communities (Parry 1975). Full discussion of past analyses is not attempted here, but two broad approaches can be defined. Piggott (1972) was unusual among archaeologists in that he worked to apply to the archaeological record of Scotland what he identified as a strong climatic signal, that is, the apparent expansion of blanket peat during the earlier Iron Age. Piggott's argument in detail has not stood the test of time (Tallis 1991; Tipping 2008). In the Netherlands, van Geel also worked from the palaeoclimatic archive to the archaeological record in evaluating the same climatic event, and has generated an increasingly complex model integrating palaeoclimatic, palaeoecological and archaeological analyses (van Geel et al 1996; van Geel et al 1998) which related abrupt climatic deterioration to elevated water tables and population dislocation, and movement away from established farmland. More recently, van Geel et al (2004) have explored the links between climate deterioration and population movements in the nomadic Scythian culture in central Europe. Van Geel and Berglund (2000) then argued that this climatic stress led, between *c* 650 and *c* 500 BC, to substantial population increases in north-western Europe, as adaptive strategies developed: environmental stress at *c* 850 cal BC is seen to have been followed by the extensive restructuring of society and its revitalisation.

Bonsall et al (2002) used this approach to examine the Mesolithic–Neolithic transition, relating relative drought, inferred from the palaeoclimatic record in the late Mesolithic, to an expansion of grassland, which, in turn, was inviting to early Neolithic pastoralists. Tipping (2010), for Scotland, and Tallavaara & Seppä (2012), for eastern Fennoscandia, have both explored the Mesolithic–Neolithic transition, but place emphasis on resource failures in undermining the ability to sustain hunting, gatherering and fishing. Davies (2007) also explored how the loss of Scots pine-dominated woodland in the northern Scottish highlands, through early Bronze Age climatic deterioration, might also have encouraged upland settlement and pastoral farming.

This approach, beginning with the climate record, tends to be more hypothesis-driven, in predicting the impact on human activity of a strong climatic signal. We should explore this approach afresh, with the explicit testing of hypotheses. Archaeologists need to know, from palaeoclimatologists, within a phase of abrupt climate change, what particular climatic stresses were damaging, their magnitude, frequency, rapidity and complexity. We need to know the 'biography' of such events, sufficient to predict what resources were affected, and then to understand what the human response to stress should have been. One strong candidate in hypothesis-testing might be to examine further the climate change at *c* 850 BC, though analysis of this and other such abrupt changes are confounded by ^{14}C plateaux, precisely because the fluctuations in solar irradiance that gave rise to these plateaux are themselves seen as causal in climate change (van Geel et al 1996; van Geel et al 1998). Another period of rapid social and technological change was the Neolithic, not just at the transition from Mesolithic lifeways *c* 4000 BC, but within it, from an early phase characterised by diversity of plant use, apparent failure of this strategy (Dark & Gent 2003), and to the maintenance thereafter of a barley monoculture, but also with continued use of wild foods (Bishop et al 2009).

We must not confuse correspondence or association in time with cause and effect. Baillie (1991) warned of the dangers of 'sucking-in' data or 'smearing' and conflating events through imprecise age controls. How tightly must we construct archaeological chronologies to fully understand cause and effect in different parts of a system? Arguably at decadal or generational timescales given the rapidity of abrupt climatic changes. Recent advances in the treatment of ^{14}C analyses make this achievable (Yeloff et al 2006; Hamilton & Haselgrove 2009; Cook et al 2010; Blaauw & Christen 2011; Bayliss et al 2011), but not without enormous investment in dating. A different approach might be to focus on archaeological materials which already allow high temporal resolution, such as crannogs dated by dendro-chronology (Barber & Crone 2001).

Defining the spatial scales of climate changes relevant to communities in prehistory is important. How do we model a causal 'cascade' from hemispheric initiation (climate shift) to what the farmer on the ground saw and reacted to? Broad-scale climatic linkages have been proposed (van Geel et al 1996; van Geel et al 1998; Barber et al 2000), drawing particularly on global teleconnections seen in the impacts of recent El Nino – Southern Oscillation (ENSO) phenomena (Glantz 1996). However, we can also recognise in the records greater regional diversity (Langdon & Barber 2005; Seppä et al 2007), for example, in wet and dry phases diachronous between east and west Scotland. Hemispheric scale impacts are translated in different ways on a regional or local scale. Climate change may not be in the same direction everywhere: climate deteriorates in one place while it ameliorates in another. There will have been communities that gained as well as lost when climate changed. This pattern is true also for other components of ecosystems that people used. There is therefore a need to work at fine-grained spatial and temporal scales. 'Broad-brush' approaches will lack the resolution required for robust interpretation.

Most archaeologists in northern Britain have worked from the archaeological record, searching in the climate record for an explanation of settlement dislocation (eg Burgess 1980, 1985; Barber 1998). Data on climate change itself were quite limited in the 1970s, and Burgess drew largely on archaeological data in relating what he saw as the collapse of later Bronze Age society (*c* 1400 to *c* 1000 BC) to climatic stress. By 1998, John Barber could draw on a range of palaeoclimatic and palaeoecological data and focused attention on events between *c* 800 and *c* 400 BC. Collaboration in these analyses with palaeoclimatologists was difficult, not least because Scotland had few palaeoclimatologists and fewer climatic records. We have more of both now (cf www.sages.ac.uk; Charman 2010). Tallavaara & Seppä (2012) show the benefit of collaboration in their analyses, and Davies et al (2004) reported on investigations which drew on palynological and palaeoclimatic records collected in tandem from the same Highland glen.

It is still rare in Scotland that analysis is designed specifically to test for climatic marginality (Parry 1975) of a site or landscape in prehistory. Targeted excavation of a location that should from *a priori* evaluation be sensitive to a specific climatic stress is one way forward. Almost by definition, this approach will be university-driven because few developer-led excavations are in areas perceived to have been marginal. But then we only explain response to stress in the most vulnerable contexts, which is both biased and self-fulfilling. We might instead explore an expected gradient of response from core area to peripheries – if core-periphery relations existed in Scottish prehistory.

In large part, however, the archaeological record is frequently inadequate to demonstrate regional or even local changes in settlement over time. More excavation and a greater focus on chronology is needed. Surviving archaeological sites are often a poor proxy for settlement (Stevenson 1975). Abandonment is difficult to date unless marked by closure (Brück 1999), and even then, hard to interpret if settlement was only part-sedentary (Gerritsen 1999) or rebuilding was frequent (Halliday 2007; Pope 2008). There is the need to make clear the differences between settlement and land use. Archaeologists, in the main, study settlement: palaeoecologists and environmental archaeologists usually study land use. They are not necessarily synonymous. The prehistoric settlement record at Lairg (McCullagh & Tipping 1998), as one example, ended in the later Bronze Age but land was not abandoned. Settlement needs to be defined more carefully. The term 'house', for instance, is a loaded term. There is a need to ask basic questions. How, for example, might we demonstrate palaeoecologically or archaeologically a strategy as common in the historic period (Bil 1990) as transhumance? How do we measure seasonality of settlement? Our understanding of the resources available to prehistoric communities, let alone what they chose to use, is very incomplete.

Palynological techniques probably provide the best proxy records for showing continuity in land use. Scotland has an extraordinary resource here, tracing processes unfolding over the *longue durée*. Given this, archaeological work might be focused on understanding settlement patterns within the pollen 'catchment' or source area of pollen records rather than vice versa. There are, however, several current weaknesses in methodology, the questions we ask or the way in which we answer them. Continuity of occupation/land use is only demonstrated when there is contiguous sampling of peat and/or lake sediments. The time interval between pollen analyses can be hundreds of years and the time captured in one homogenised sample extending over many decades (Tipping 1994). Interpretation at generational timescales in both archaeological and palynological records, probably that most appropriate to understand decision-making in societies, needs to be the baseline. Palynological interpretation probably works best at spatial scales larger than that of the single excavated archaeological site: there can be a mis-match between archaeological and palynological interpretation because of this. Pollen diagrams reflect pasture better than they do arable farming because cereal pollen is not dispersed far from the crop, which highlights the importance of incorporating and integrating evidence from all other records. Reconstructing, in any quantitative way, the proportions of land cover represented by different plant communities or land uses is at an early stage, though tools to do this are being developed (Sugita et al 1999).

What in the archaeological or palaeo-economic records might be compared to the climate record? What do we expect to have changed? How is this best measured? In the past, these questions have often been poorly framed or asked with little subtlety. It is difficult to exaggerate the importance to archaeologists 'of a certain age' in Scotland of Martin Parry's ideas on 'retreat from the margins', developed for the 'little ice age' in south-east Scotland (Parry 1975), yet they are simplistic. There is no space in this interpretation for people to have made a considered response to stress, an evaluation of risk and successful adaptation. Positive responses to climate change by prehistoric communities need to be explored: failure, if we could define this, and retreat are only two consequences. The catastrophist interpretations of recent syntheses (Diamond 2005) have provoked sharp responses (McAnany & Yoffee 2010). Collapse is rare in case studies: social restructuring and resource switching were probably more common responses. There is a need to be sensitive to what was seen as success or failure. Subsistence farmers may simply have seen their survival in 'bad' years as successful (Halstead & O'Shea 1989). More complex societies, on the other hand, might have been constructed in ways that prevented coping strategies to emerge, being path-dependent with a rigidity of decision-making, constraining the freedom to adapt. We need to acknowledge the enormous complexity of the ecological and social systems we are examining (Gallant 1991) as well as how little of this complexity survives.

Innovation is one probable positive response. Introductions might be identified in the archaeological record – although their discovery would be biased to periods typified by archaeological sites that are highly visible. Innovation in this context is a form of agrarian specialism. Doing what you are good at is one coping strategy. In an historical context, Thirsk (1997) showed that farmers stopped experimenting in periods of environmental stress. The adoption by farming communities of a down-scaled, retrogressive broad-spectrum strategy incorporating hunting is another, almost diametrically opposed response (Zvelibil 1996; Schribler 2006). Changes in farming practice might be another response (McCormick 1998). The introduction, for example, of the hand rotary quern in later prehistory is one marker. Another might be the emergence of large co-axial field systems in southern Britain (Yates

2007). Invention is much more difficult to identify than adoption, however. There might be a substantive temporal difference between invention and common usage: the slow diffusion of ideas is one explanation for the blurred appearance of some archaeological transitions in prehistory (above). We perhaps under-estimate the rapidity of the diffusion of ideas and techniques in non-literate societies. Neolithic ideas and things spread across the British Isles very rapidly indeed (Bayliss et al 2011). Faced with abrupt climate change, communities would need to absorb key innovations quickly or be lost.

How people in the past perceived environmental and climate change is central to our understanding of their responses to them. Every society has their ontology and cosmology. Past communities will have included change within their world-view and attempted to make sense of this through their stories. It may prove difficult to talk in general terms about societal responses to stress because these may have been contingent on experience and belief, but we need to try. Post-processual approaches are highly significant in this. There is a danger in making interpretation overly scientific and reductionist. There is a need to move beyond the subsistence base. A spectrum of approaches needs to be integrated.

Larsson (2003) came close to the core of the problem in asking what effect the elm decline, a significant reduction of elm trees from woods throughout north-west Europe around 3800 BC (Parker et al 2001), had on Mesolithic perceptions of nature. In parts of northern Scotland, other trees also died at the same time, like the Scots pine (Tipping et al 2008). Hunter-gatherer societies today tend to have an implicit faith in nature to provide for them (Brody 2001; Barnard 2007), often with complex ideologies by which to live, to ensure nature continues to be bountiful. What must the effect on their world-view have been when trees started to die? In some societies, such a crisis is regarded as punishment for societies' failings (Bollig 2006). Might this have led to the adoption of agriculture by hunter-gatherers? The earliest Neolithic 'slighting of the sea', on the western seaboard of Scotland (Schulting 1998; Schulting & Richards 2002) has been described as a food taboo (Richards 2004; Schulting 2004; see also Jones 2007: 162–3 for a southern English example in the same period). Was this taboo a practical response to a failing resource? We need to ask these questions and not be intimidated that our own world-view might change in the process.

CONCLUSION

The geography and archaeology of Scotland makes it an ideal location to better understand the nature and timing of abrupt climate change on the landscape and the prehistoric societal response to such dramatic resource fluctuations. The wealth of recorded archaeology and the extent of peat and sediments with continuity of record and a high degree of temporal resolution suggests (even demands) that we should be able to explore phases of Holocene climate change, abrupt or gradual, and the human response to such change. We should be able to move from the simplistic 'stay' or 'run away' responses to more subtle responses involving innovation, adaptation, and survival with or without prosperity. However, understanding such complexity from archaeological data is problematic and palaeoenvironmental analyses, limited by resource issues, are still a long way from achieving timescales useful to understanding human decision-making. In this paper we have argued for a more strategic, hypothesis driven approach to explore suggested key moments of crises (*c* 3600–3300 cal BC; *c* 3000/2900 to *c* 2700 cal BC; *c* 850 to *c* 500 cal BC). These moments or phases may prove to be fertile testing grounds in which to target and integrate archaeological evidence with palaeoenvironmental data meaningful at generational timescales.

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