Late Holocene Vegetation Change, Climate Deterioration and Human Response in the Strath of Kildonan, Sutherland, Scotland

An Investigation into the Theory of Settlement Discontinuity during the Later Bronze Age

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Declaration

The research and writing of this thesis was carried out solely by Darcey Francis Gillie. Where the work of others has been quoted, it is duly acknowledged.

Darcey Francis Gillie, September 2003

Abstract

Using complementary methods of palaeoecological reconstruction (pollen, microscopic charcoal, organic content, peat humification and tephrochronology) integrated with a critical and contrastive re-evaluation of archaeological data, this PhD project is the first to test the hypothesis that marginal, upland settlements were abandoned because of 'catastrophic' climatic or environmental changes during the Later Bronze Age (*ca.* 1200 BC). The Strath of Kildonan possesses a remarkably rich and well preserved record of multi-period settlement and land-use situated in an area, currently and historically, perceived as culturally, economically and environmentally 'marginal'. Previous archaeological work has been used to support the abandonment hypothesis, making it an ideal location for reconstructing associated palaeoclimatic and vegetation changes from 'off-site' environmental contexts. There are no extant palaeoclimatic reconstructions and existing pollen work is of low spatial/temporal resolution. Three deep peat sites were selected for their relationship to archaeological sites which reflect a gradient of increasing ecological 'marginality', thus sensitivity to climate change.

Palaeohydrological reconstructions reveal a highly variable Late Holocene climate with regional shifts recorded *ca.* 4,360-4,090 cal BP (*ca.* 2410-2140 cal BC); *ca.* 3,160-2,870 cal BP (*ca.* 1210-920 cal BC); 2,160-1,940 cal BP (*ca.* 210 cal BC-cal AD 10); *ca.* 1,520-1,350 cal BP (*ca.* cal AD 430-600). Pollen- and peat-stratigraphic data reflect the continuity of settlement, through the record of land-use, during and after the inferred Late Bronze Age climate deterioration *ca.* 3,160-2,870 cal BP (*ca.* 1210-920 cal BC) at the two most marginal sites, Loch Ascaig and Kinbrace Hill. The only significant evidence for abandonment occurs at Loch Ascaig substantially *before* the palaeohydrological shift *ca.* 1,520-1,320 cal BP and persists for *ca.* 200 years.

The results of the palaeoenvironmental programme and re-appraisal of the archaeological record in the Strath of Kildonan, northern Scotland, have led to a rejection of a Later Bronze Age 'catastrophe' as a stimulus of land-use change and settlement abandonment. There is no evidence that climatic change or Icelandic volcanic eruptions were detrimental to 'marginal' agricultural settlements in the Strath of Kildonan during the past 4,000 years. The results both challenge environmentally deterministic interpretations and also highlight some of the ways which culture and cultural adjustments provide strategies for coping with times of uncertainty and scarcity. This research has highlighted the importance of examining how settlements and landscapes were inhabited and transformed by the dynamic interaction of human activity, climatic variability and internal environmental processes, not merely identifying the 'if' and 'when' of abandonment.

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"A man receives only what he is ready to receive, whether physically intellectually or morally... We hear and apprehend only what we already half know...Every man thus *tracks himself* through life, in all his hearing and reading and observation and travelling. His observations make a chain. The phenomenon or fact that cannot in any wise be linked with the rest which he has observed, he does not observe."

Henry David Thoreau, *Journal* January 4, 1860

"I went to the woods because I wished to live deliberately, to front only the essential facts of life, and see if I could not learn what it had to teach, and not, when I came to die, discover that I had not lived. I did not wish to live what was not life, living is so dear; nor did I wish to practice resignation, unless it was quite necessary. I wanted to live deep and suck out all the marrow of life, to live so sturdily...as to put rout to all that was not life, to cut a broad swath...to drive life into a corner, and reduce it to its lowest terms, and, if it proved to be mean, why then get the whole and genuine meanness of it, and publish its meanness to the world; and if it be sublime, to know it by experience..."

Henry David Thoreau "Where I lived and what I lived for" *Walden*, 1854

Chapter 1

A Later Bronze Age Catastrophe...?

> "The human understanding is no dry light but receives infusion from the will and affections... For what a man had rather were true he more readily believes. Therefore he rejects difficult things from the impatience of research; sober things because they narrow hope; the deeper things from superstition...Numberless in short are the ways, and sometimes imperceptible, in which the affections colour and infect the understanding."
>
> Francis Bacon, *Novum Organon* 1605

Introduction

The role climate plays in cultural change and continuity has long been a key theme in archaeology. A particular case is the numerous and varied claims that climatic deterioration during the Later Bronze Age (ca. 1200 BC), possibly in association with a volcanic eruption, caused the widespread collapse and abandonment of 'marginal' upland agriculture in Britain. The reality of climate change is undeniable; frequent variations in the climate system during the Holocene are increasingly well documented at a number of spatial and temporal scales. However, the geographical extent, indeed the reality, of the proposed Later Bronze Age 'catastrophe' is increasingly contested. This PhD project was conceived in response to the need for a serious empirical challenge to generalising and sensationalist studies which have, at times, eclipsed more considered, contextualised discussions of later prehistoric archaeology.

The project is unique in a number of ways. It is the first study to:

- Specifically test the hypothesis of a Later Bronze Age 'catastrophe'.
- Generate parallel reconstructions of climate and vegetation changes on spatial/temporal scales directly relevant to human experience.
- Test ideas of ecologically defined hierarchies of later prehistoric settlement.

The following benefits flow from examining these issues:

- A more detailed perspective of the physical and biotic contexts of past human life emerges from the application of diverse, complementary sediment analysis methods applied at high temporal resolution (pollen, microscopic charcoal, organic content and peat humification).
- The emphasis on synecology offers insight into the active role of people in ecological transformation, incorporating an appreciation of human behavioural

complexity and historical process as an 'antidote' to environmental determinism.

- A more critical and contrastive approach to the archaeological data redresses some of the more significant misconceptions of later prehistoric settlement in northern Scotland which have resulted from earlier limitations in archaeological research design, practice and interpretation.

Crisis in the Second Millennium BC

> "What came after, in the early First Millennium, bore no resemblance to what had gone before in the Second."
>
> Colin Burgess (1989:325)

The landscape of Britain underwent a profound re-organisation during the second millennium BC, or the British Early Bronze Age (Parker-Pearson, 1999). The emotive, iconographic 'ritual landscapes' of chambered tombs and standing stones gave way, by 1500-1200 BC, to the emergence of a 'secular' landscape dominated by settlements and field systems (Hill, 2001). These settlements expanded onto and exploited the marginal soils of the uplands, encouraged by both the onset of climatic warmth and dryness not seen since the early Holocene 'Climatic Optimum' (*cf.* Lamb, 1981; Taylor, 1980) and a rising population (Mercer, 1981; Burgess, 1984, 1985, 1989; Fleming, 1978). From the early to the middle of the second millennium BC, settlement expanded into the uplands across the width and breadth of the British mainland; from Caithness (Mercer, 1980) toCornwall (Johnson, 1980) and Dartmoor (Fleming, 1978). On Dartmoor, by 1400 BC the landscape was parcelled into highly organised subdivisions separating arable zones from pastoral/moorland zones (Fleming, 1978) (Figure 1.1). According to one archaeologist "... this *floruit* of arable agriculture blurred the distinction between the Highland and Lowland zones..." (Mercer, 1981:xv). Although many comparable upland areas of Scotland lack the meticulous apportionment of the landscape apparent further south (Figure 1.2), both the archaeological (McCullagh & Tipping, 1998) and palaeoenvironmental (Tipping, 1994) records support the expansion of farming, particularly arable, into previously unexploited upland areas.

When the period of climatic amelioration came to an end at the beginning of the Later Bronze Age *ca.* 1200 BC (Lamb, 1981; Piggott, 1972; Taylor, 1980; Turner, 1981), these marginal upland settlements were abandoned (Burgess, 1974, 1980, 1985, 1989, 1995). The intensive land use practices which emerged in the Earlier

Bronze Age had, it was believed, caused irreversible degradation to the marginal upland soils, and the onset of the cooler, wetter conditions with the transition to the sub-Atlantic period encouraged the spread of blanket peat, smothering the formerly productive fields (Fairhurst & Taylor, 1971; Romans & Robertson, 1975). Based on Parry's (1978; 1985) work investigating the impact of Little Ice Age (AD 1550-1850) climate changes on upland settlements in the Lammermuir Hills of southern Scotland, it was estimated that viable altitudes for cultivation declined by 150m between 1200 and 700 BC (Burgess, 1985). Although Burgess noted that there was some evidence for the relocation of settlements to the Thames valley in southern England, the impact of climate change was not restricted to the uplands; very few areas of Britain, upland or lowland, escaped the crisis of the second millennium BC (Burgess, 1980, 1985). This 'muddy catastrophe' (Whittle, 1981:192) induced by climate change, argued Burgess (1980,1985, 1989), had a deleterious impact on population as famine, plague and warfare stalked the land in its wake.

This view of cultural change and settlement re-organisation in later prehistoric Britain as a consequence of climate change has not gone unchallenged, however. Increasingly, many interpret the changes in the archaeological record which archaeologists use to delineate the Earlier Bronze Age (1500-1200 BC) from the Later Bronze Age (1200-700 BC) as the culmination of complex social discourses (Bradley, 1991; Barrett *et al.*, 1991; Harding, 2000; Hill, 2001; Young, 2000; Young & Simmonds, 1995, 2001; Whittle, 1981), rather than environmentally driven. In particular, several publications including Barrett (1999), Young (2000) and Young and Simmonds (1995, 2001) have thoroughly questioned both the conceptual and substantive base underpinning many of the arguments for a Later Bronze Age catastrophe in, for example, the context of the Anglo-Scottish Borders region (Young, 2000; Young & Simmonds, 1995, 2001).

However, as Cameron comments, "...archaeologists are not immune to the 'disaster movie' mind set" (1996:3). More recently, the theory of a Later Bronze Age catastrophe has been expanded, rather than diminished. A palaeoclimate reconstruction from the Netherlands reveals a sharp rise in atmospheric ^{14}C between 850 and 750 cal BC thought to reflect a shift to cooler and wetter climate

conditions in NW Europe (Kilian *et al.*, 1995) (Figure 1.3). Subsequently, this inferred climate deterioration was linked to the abandonment of coastal settlements in the Netherlands and through climate 'teleconnections', climate change and settlement abandonment on a global scale (van Geel *et al.*, 1996, 1998; van Geel & Renssen, 1998) (Figure 1.4). Publications continue to endorse the Later Bronze Age catastrophe scenario, culminating in the recent volume, *Natural Catastrophes and Later Bronze Age Societies* (Peiser *et al.*, 1998). The debates concerning the role of climate change in cultural change are not confined to any single area of the world, nor any particular period of time. Climate change has been invoked to explain events as far apart in time place as the abandonment of the Four Corners Region of the American SW at AD 1300 (Schlanger & Wilhusen, 1996), the collapse of Mayan civilisation from AD 760 (Curtis *et al.*, 1996) as well as the transition of NW Europe from the Bronze Age into the Iron Age.

The Premises

> **Catastrophe** [k'tastr□f●] *n.* **1.** A disastrous conclusion; overthrow, ruin, calamitous fate. M16. **2.** A revolutionary event. L.17 **b.** *Geol.* (An event causing) a sudden upheaval or discontinuity in the stratigraphic record. M19. **4.** A sudden or widespread or noteworthy disaster; an extreme misfortune. M18.
>
> *The New Shorter Oxford Dictionary* 4th edition s.v. "catastrophe".

The impact of climate change on settlement in 'marginal' areas has always been the focal point of the argument. The net has since widened to include the impact of volcanic eruptions (*eg.*, Baillie, 1989; Baillie & Munro, 1988; Burgess, 1989) and even a bolide (meteorite) impact (Franzen & Larssen, 1998) as explanations for cultural change. As yet, there has been no attempt to investigate the inferred relationship between climate change or any other phenomena and Later Bronze Age settlement discontinuity with a directed research programme. Archaeological evidence for a global climate change/settlement contraction proposed by van Geel & Renssen (1998; also van Geel *et al*, 1996, 1998) is little more than a shopping list of archaeological abandonments whose 'dates' appear to overlap with the rise in ^{14}C identified in the peat sequence from Engbertdijksveen (Kilian *et al.*, 1995). For example, the British evidence marshalled to support the argument for a global catastrophe (van Geel & Renssen, 1998) is an undated hut circle in Cornwall which 'looked like' it had been abandoned at the sub-Boreal/sub-Atlantic transition.

Despite engendering a lively debate in archaeological and palaeoenvironmental research, there has been a singular lack of discourse on the validity and appropriateness of many of the 'off the peg' (Young, 2001) explanations of changing settlement patterns and climate change in later prehistory. Figure 1.5 illustrates and summarises the inferential structure used to construct the architecture of Later Bronze Age Catastrophe. Each of the supporting beams represents one of the main premises on the which this belief is grounded. The following discussion will consider the ways in which **climate deterioration** and **volcanic eruptions** are inferred to have impacted **marginal** settlements. It will present the evidence used in support of the ensuing **population crises** and settlement **abandonment** caused by these 'catastrophic events', which includes **forest regeneration** and a **lack of radiocarbon dated** settlements belonging to the period 1200-900 BC. The discussion incorporates critiques of the strengths and limitations of other workers in the field and ways which thinking has moved forward. The purpose, ultimately, is to create a more informed platform from which to investigate the human response to climate change in a marginal environment, the Strath of Kildonan, Scotland.

Climate Deterioration

The Historical Context of Palaeoclimate Reconstruction

Investigations into the relationship between past peoples and climate change is not recent development. In NW Europe, systematic studies into peat bog stratigraphy have long provided proxy data for terrestrial climate change since the late 19th century (Barber, 1981, 1982; Blackford, 1993 for reviews). The pioneering work of Blytt (1876) and Sernander (1908) formed the environmental basis of approaches towards investigations of human-climate relationships for most of the 20th century. This was only fitting. Before the advent of radiocarbon dating, the archive of environmental change preserved by peat bogs and elucidated by Blytt and Sernander was closely tied to the archaeological record. Artefacts, either singly or in hoards, found in the peat provided the only means of dating the peat and pollen stratigraphic changes. The dates of the artefacts themselves were

usually formulated from historical cross-datings with Mediterranean cultural sequences (Harding, 2000; Kristiansen, 1998).

Blytt's observation of preserved tree stumps in highly humified (well decomposed) peats in bogs in Denmark led him to suggest that drier climate conditions must have existed in the past. Meanwhile, in Germany, Weber (1900) coined the term *grenzhorizont* ('boundary horizon') for the major change from highly humified peat to fresh, well preserved *Sphagna*, and inferred change to wetter, cooler climate conditions. Weber estimated the age of the *grenzhorizont* to between 800 and 500 BC through its association with a shield ascribed to the early Halstatt period (Piggott, 1972). Blytt's work was developed by Sernander (1908), also in Denmark, who correlated changes in peat bog stratigraphy with changes in lake levels, archaeological periods and plant immigration as evidenced by macrofossils (Blackford, 1993), resulting in the now familiar scheme of major Holocene climate zones (Table 1.1).

Blytt-Sernander Period	**Pollen Zone**	**Description**	**Evidence**	**Years Before Present/**
Sub-Atlantic	VIII	Cold & wet	**Deterioration** Poorly humified *Sphagnum* peat	2,500-present
Sub-Boreal	VIIb	Warm & dry	**Climatic Optimum** Pine stumps in humified peat	2,500-5,000
Atlantic	VIIa	Warm & wet	**Climatic Optimum** Poorly humified *Sphagnum* peat	5,000-7,000
Boreal	VI V	**Warm & dry**	Rapid amelioration/climatic Optimum Pine stumps in humified peat	7,000-9,500
Pre-Boreal	IV	Subarctic	**Rapid amelioration** Macrofossils of subarctic plants in humified peat	9,500-10,000
Younger Dryas	III		**Cold**	10,000-10,500
Alleröd	II		**Rapid amelioration**	10,500-

Table 1.1. Blytt-Sernander scheme, pollen zones and descriptions of Holocene climate. After Bell & Walker, 1992.

While Sernander was undertaking his investigations in Danish bogs, Lewis (1905, 1906, 1907, 1911) was conducting further research into Scottish bogs and suggested that there was evidence to support at least two prior warm, dry periods in British climates, the Upper Forestian and the Lower Forestian. Other work by Granlund (1932) involved the archaeological cross-dating of a series of 'recurrence surfaces' from peat bogs in Sweden: RYI (1200 AD), RYII (400 AD), RYIII (600 BC), RY IV (1200 BC) and RYV (2300 BC).

Some of the earliest radiocarbon-dated proxy climate evidence was obtained from the Somerset Levels (Piggott, 1972, Turner, 1981 for reviews). The peat stratigraphy reflected drier conditions prior to 850 BC, with a gradual shift to wetter conditions through the mid-first millennium BC, coinciding with the construction of the now famous trackways across the bog. Aaby (1976) showed that radiocarbon-dated shifts to wetter conditions were coincident in five Danish peat bogs in the middle of the first millennium BC, and in particular recorded a shift at 2,500 BP (or *ca.* 850-650 cal BC). Remarkably, these findings broadly agreed with the estimations of the earliest studies. More significantly, the early [mis-]understanding of how peat bogs grow, reinforced the belief of broad, large scale shifts in past climate. Within the last 30 years, however, there has been a growing recognition and understanding that the climate varies on numerous spatial and temporal scales (Mitchell, 1976, Overpeck, 1995). Barber (1981) was able to demonstrate that peat bogs reflect highly variable, continuous and detailed proxy records of climate change related to effective precipitation and temperature. The body of proxy climate evidence from peat bogs has been added to considerably in the past two decades and is considered in more detail in Chapter 2.

Piggott (1972) was the first to make an explicit connection between the inferred climate change between 1000-600 BC and the decline of trade between southern Britain and the continent. He suggested that stormier conditions would have made sea travel more dangerous. The suggestion that climate change might have had a significant impact on prehistoric populations gained in popularity (Burgess, 1974, 1980; Coles & Harding, 1979; Fleming, 1976; Mercer, 1981), however, it was Turner (1981) who provided the first critical review of the evidence for climate change and its archaeological implications. Although Turner chose to ignore ice

core data and marine records from the North Atlantic region, considering them not directly relevant to Britain, from the summary of peat bog records from NW Europe and the British Isles it seemed clear that between 1000-600 BC there was an onset of cooler, wetter conditions, followed by warmer, drier conditions around 400-450 BC.

Archaeological Perspectives of Climate Change and People

The pro-catastrophe literature reflects little consideration of what climate and climate change might mean. 'Climate deterioration' has become a convenient catch all to explain otherwise apparently inexplicable alterations in the prehistoric settlement record. In the present day, meteorologists measure climate as the accumulation over 30-year intervals; the significance of any changes are measured in two ways: 1) statistically, as represented by a body of data and 2) subjectively, contingent on the feelings of those who experience it. Measuring climate in 30-year intervals is not possible with most of the techniques available to archaeological and palaeoclimatic studies, with a few exceptions including dendro-chronology and –climatology. However, not only the frequency of climate change is critical, but the amplitude, temporal and spatial scales of changes must be understood. Is variation within the 'normal' range? Or has the climate 'shifted' to a different state (*cf.* Dean, 2000) ?

The historical geographer Martin Parry (1978) argued that only long term ('secular') climate shifts matter to people, short term variation is unlikely to provoke long term responses, such as abandonment. McGlade (1995), on the other hand, has suggested that such a focus on long term average values unduly minimises the importance of rare high magnitude perturbations in weather or fluctuations in climate, particularly in perceived 'marginal' environments. Archaeologists have suggested that the human ability to adjust to high frequency changes in the climate system lies in the ability to pass information on and evaluate the recurrence of bad events (McGlade, 1995; McGlade & van der Leeuw, 1997; McIntosh *et al.*, 2000; van der Leeuw, 2000). Low frequency changes in climate on longer timescales of over several decades, centuries and even millennia are more difficult for people to tolerate because of the break down of 'social memory', the means of transferring learned information about, for example, the

weather (see also McGlade, 1995). Coping strategies may be stored in and transmitted through oral tradition, particular objects, places in the landscape, rituals, and phenologies* (Trigger, 1997).

Some archaeologists, clearly frustrated by the continued reliance on environmental determinism as an explanatory framework in archaeology have called for a more dynamic approached to the problem. Early on, Whittle (1981) provided a cogent criticism against what he saw as the invocation of a 'crude environmental determinism' (1981:192), using climate change as a basis to investigate social and economic change. As he, and others since have noted, the reality of climate change in later prehistory can hardly be doubted, but he criticised the general tendency to see climate change as uniformly harmful "...in all activities, at all seasons, and over the country as a whole". (1981:192). More importantly, in terms of the rationale behind this thesis, he urged archaeologists to actively investigate the purported impact of climate variability, rather merely *assuming* the effects. Dincauze (2000) has criticised the persistent search for cause and effect between environmental change, climate change and cultural change altogether because it draws attention away from elucidating the processes and mechanisms that link the behaviour of natural systems to human systems. To do this, Hill (2001) has suggested archaeologists focus on illuminating the aspects of 'every day' life in prehistory, rather than focusing on structures, such as the environment, and assuming prehistoric peoples are merely reflections of ourselves, with our same desires, prejudices and rationales.

Archaeological approaches which reduce humans to environmentally controlled automatons are incorrect because humans have a range of adaptive and coping strategies at their disposal and it is unreasonable to assume that people always make the 'best' decision (Butzer, 1982; McGlade & van der Leeuw, 1997; van der Leeuw, 2000). In addition, people will only respond to changes they perceive (Dincauze, 2000; van der Leeuw, 2000). Short term changes are absorbed by individuals and may result in adjustments to, for example, scheduling of rituals,

*Phenologies can take many forms. Some can be as informal as my grandfather's observation that beans should be planted on June 11th and corn when 'the leaves on the birch trees are as big as squirrels ears'. My father plants his beans on June 11th because my grandfather planted his beans on June 11th A more formal example of phenology is *The Old Farmer's Almanac* which has been keeping track of similar phenomenon in North America, more or less, since 1792.

resource procuration and exchange of goods, seasonal changes in settlement pattern or sizes of groups through fission, fusion, or emigration, and minor changes in technologies (Dincauze, 2000). Only long term changes will generate major cultural responses, but these may be the accumulation of many different strategies, incorporating different mechanisms, lag times, as well as adjustments made to both internal crises and sub-optimal decision making (Butzer, 1982; Dincauze, 2000; McGlade & van der Leeuw, 1997). In short, adaptive responses to climate may be difficult to identify archaeologically, but more importantly, if identifiable, are not necessarily synchronous with climate changes identified in proxy climate reconstructions.

Consensus is only slowly evolving on the appropriate scales which to consider the significance of climate change on prehistoric human communities. Still a contested issue is the possibility of identifying and appropriately attributing responses from archaeological data sets. Even with mounds of historic documentation, the overall impact of the Little Ice Age is still disputed, as highlighted by Tipping's (1998) test of Parry's hypothesis. While it is beyond the scope of this thesis the formulate more appropriate 'metrologies' (*cf.* Wobst, 1997) towards the identification of human agency in the archaeological record, it is important to remember van der Leeuw's (2000) observation that people are not like trees or animals but are observing, perceptive, thinking, decision making beings. To this it might also be reasonably also be added that they are often unpredictable, capricious and often short-sighted in their needs and decision-making. As much as the environment may be thought to constrain human activity, environments for thousands of years have been created and re-created by human innovation and ingenuity. As illustrated by Clarke (1968) and re-iterated by Barrett (1999), environment and society cannot be reduced, but must be considered together as the 'total' environment which humans inhabit.

Recent work has raised other questions about how archaeologists view climate-human interactions. Barber (1981, 1982) draws attention to the possibility that perhaps the Early Bronze Age climate was not as 'optimal' as previously assumed. Research has indicated a major shift to wetter conditions in peat bogs in Britain (Barber *et al.*, 1994, Chambers, *et al.*, 1997; Hughes *et al.*, 2001) and across

Europe around 4,000 years ago (Chapter 2). This shift has been identified as a causal factor in the disappearance of pine from northern Scotland (Birks, 1988; Gear & Huntley, 1991; Huntley *et al.*, 1998). It is also recorded in regional proxy climate records from all over the North Atlantic region (Chapter 2). Growing evidence is clearly at odds with previous interpretations of the Early Bronze Age agricultural expansion as a time of climatic amelioration (Tipping, 1994). "In pursuit of a universal causal factor — climate — history and process have been left out" (Tainter, 2000:337): why did the deterioration of climate at 2200 BC stimulate the colonisation of the uplands , but a similar event result in abandonment 1000 years later? How was climate able to initiate two different cultural responses (*cf.* Tainter, 2000)? One potential solution, is that perhaps climate change, *sensu stricto*, was not responsible for the breakdown of society from 1200 BC.

Volcanic Eruptions

Putative Impacts and Settlement Change

The argument for a widespread discontinuity in the settlement record was given renewed momentum by Baillie's (1989) publication linking narrow tree rings recorded in ancient bog oaks from Ireland dating to *ca.* 1159 BC to the eruption of Hekla, radiocarbon dated to 1021 +130/-100 BC (Larsen & Thorarinsson, 1977; Dugmore *et al.*, 1992,1995), as well as other 'events' (Figure 1.6). The eruption of the volcano would have created a dust veil effect (*cf.* Lamb, 1970) in the atmosphere, causing widespread cooling of the climate, with increased cloudiness and precipitation (Baillie, 1989). At the time when Burgess (1989) expanded his thesis on the crisis of the second millennium BC to include volcanoes (Figure 1.7), the presence of microscopic layers of tephra (volcanic ash) in Britain was only just beginning to be realised (Dugmore, 1989). The search for tephra in sediments in Britain was first undertaken for the potential of these layers to provide chronostratigraphic markers (Dugmore, 1989; Dugmore *et al.*, 1995). However, once the presence of tephras from Icelandic volcanic eruptions was detected in Scotland (Dugmore 1989, Dugmore *et al.*, 1995) the significance of these layers quickly transformed from chronostratigraphic markers to their potential as agents of environmental change (*eg.*, Blackford *et al.*, 1992; Charman *et al.*, 1995; Grattan & Gilbertson, 1994).

The eruption of Laki 1783 became emblematic in the debate about volcanoes, climate, environmental change and people. The proximal effects of the eruption are well documented, both through eyewitness accounts as well as through subsequent scientific research (Thordarson & Self, 1993). Laki 1783 was a basaltic eruption, lasting for 8 months, and characterised by one of the largest outpourings of lava known in recorded history but relatively low tephra production (Thórarinsson, 1979). The principle atmospheric output from the eruptives consisted of the slow de-gassing of dry sulphur and fluorine compounds, responsible for high mortality rates in Iceland of both livestock and people, as well as a deleterious impact on local fisheries. In Iceland, famine conditions prevailed from 1783-1786, as a direct result of the fall out, and the eruption is also inferred as the cause of a 1-2°C decrease in surface temperatures in the Northern Hemisphere between 1783-1785 (Thordarson & Self, 1993).

From North America to Europe, historical accounts of cooler conditions, dry fogs, acid damage to vegetation and fish are all attributed to the acid fallout from Laki 1783 (Charman & Grattan, 1994; Grattan & Charman, 1994; Grattan & Gilbertson, 1994; Grattan & Pyatt, 1994). The eruption has even been held responsible for the 'third great disaster' in the history of the Kauwerak people of NW Alaska (Jacoby *et al.*, 1999). The analysis of the impact of the Laki fissure eruption is a serious issue because the observed effects across wide geographic areas have been used to infer the impact of past Icelandic eruptions on prehistoric populations in upland Britain and support the case for abandonment and catastrophe (*eg.*, Grattan & Gilbertson, 1994). However, the construction of analogy , like the Laki 1783 eruption, does not provide an answer. Equivalence must be made evident, not assumed; reasoning by analogy may help identify the critical parameters in a given situation and direct research, but they are not explanations in themselves (Dincauze, 2000). Subsequent work indicates that the relationship between Laki 1783 and climatic perturbations and environmental degradation may not be as straight forward as assumed, and the apparent coincidences used above need to be evaluated against a dynamic environment in which change can be stimulated in a number of ways.

Buckland *et al.*(1997) effectively dealt with the highly linear and formulistic approach taken by Baillie (1989), Burgess (1989) and others who attempt to causally link volcanoes, narrow tree rings, climate and cultural change. Despite the cautions of Buckland *et al.* (1997), arguments persist in attributing cultural change in northern Britain during prehistory to volcanic eruptions. In particular, it has been argued that the Strath of Kildonan was abandoned in the 12th century BC (Barber, 1997) as a result of the Hekla 3 eruption. Analogies have been drawn with the consequences of the Laki 1783 eruption in order to 'prove' that the Strath of Kildonan and other marginal, upland areas would have been sensitive to the fall out from Icelandic eruptions in prehistory (Grattan & Gilbertson, 1994, Grattan & Pyatt, 1994; Sadler & Grattan , 2001).

Zielinski *et al.* (1995) analysed tephras found in the GISP2 ice core believed to be associated with the AD 930s eruption of Eldjá in Iceland. The tephra shards coincided with an acidity peak dated to AD 938±4, but showed poor correlation with evidence for Northern Hemispheric cooling. Zielinski *et al.* (1995) indicate that Eldjá may have caused greater atmospheric aerosol loading than Laki 1783. They suggest that the AD 930s eruption of Eldjá may have occurred over longer time period under better climate conditions, diffusing any potential climate impacts. The authors note evidence which indicates that Laki 1783 occurred when climate conditions were already cool prior to the eruption, and the system was perhaps more vulnerable to perturbation.

The debate about the proximal and distal, direct and indirect, impacts of volcanic eruptions is not restricted to the North Atlantic region. Both Buckland *et al.* (1997) and more recently Dincauze (2000) have summarised the ongoing debate concerning the impact of the eruption of Thera on Aegean civilisations. The direct and proximal effects of Thera on the island of Santorini are clearly evident, but more controversial is the role, inferred by some, of the eruption in the decline of the Minoan civilisation of Crete some 120km distant from the island of Santorini and the volcano Thera. It is obvious that volcanic eruptions *do* happen; climatic perturbations *can* happen; impacts on the environment *may* happen; and that eruptions *might* have consequences for human populations. However, the connection between volcanism and climatic impacts relies on temporal

coincidence, and would seem necessary to employ caution when attempting to link specific eruptions with climate changes, or indeed evidence of change from the archaeological record (Buckland *et al.*, 1997).

Population Crises: Three Possible Causes and Their Influence on Settlement Change

Conflict

There is an element of tautology inherent to the Burgess' formulation of a crisis in the second millennium BC. In a 1968 publication, he first suggested that a gap in the pottery sequence from southern Britain, between the Deverel-Rimbury tradition (from *ca.* 1600 BC as it was then understood, to 1000 BC) and the pottery styles that emerged in the early Iron Age, then considered to be *ca.* 500 BC. To 'explain' the apparent break in the ceramic tradition and the change in ritual focus at the end of the Bronze Age from the celestial to the subterranean and 'watery' places, it was suggested that these changes signalled the rejection of the old gods, and an appeal to a new set of gods in the face of water-logging and flooding caused by climate deterioration (Burgess, 1974). No hard evidence was presented linking these cultural changes with evidence for climate change in Britain, then largely provided by Piggott's (1972) publication. More recent estimates place the 'start' of the Iron Age closer to 700 or 750 BC (*eg.* Hingley, 1992; Haselgrove, 1999). The re-evaluation of material from the early Iron Age led to the conclusion that much of this material was in fact earlier, and this 'post-Deverel-Rimbury' ware adequately filled the gap between 1000 BC and 500 BC (Haselgrove, 1999).

Subsequently, Burgess (1985) identified a second potential break in the record of later prehistoric material culture which also suggested to him that cultural changes were taking place due to unusual circumstances. Finds of bronze axes are argued to decline markedly between 1200 and 900 BC (Figure 1.8), the apparent replacement of these objects by weaponry marks the increase in conflict as communities competed for declining resources (Burgess, 1985; 1989). Not only that, but declining axes also indicate declining users in the period 1200-900 BC. Burgess confesses that critics of his approach might "quibble" because "... it cannot be demonstrated that single finds of axes reflect the amount of metal in

everyday use. This must be a matter of opinion..." (1985:207). The declining numbers of artefacts, *ie.*, population, are blamed on famine and plagues, related to the climatic deterioration (Baillie, 1989; Burgess, 1985, 1989). To illustrate the scope for plague and famine during prehistory, analogies are drawn with the Black and Justinian plagues (Burgess, 1985).

Interpreting the role of axes in everyday Bronze Age life, and their potential 'replacement' with weaponry, is not as straightforward as argued (Burgess, 1985), however. Some have suggested that the axe may have gradually lost its status to weaponry in western Europe; bronze axes rather than being everyday tools, may have provided been produced as ingots (Bradley, 1998), a form which allowed easy storage and transport, as well as possibly holding some special semiotic meaning. Rather than being a common domestic tool, as argued by Burgess, axes may have enjoyed a special and circumscribed status. This premise, which excludes metal work found in hoards, also ignores the fact that settlement assemblages, in their own way, are as partial as hoard material: they can be formed by selective processes such as storage and ritual disposal or placement, not just simple loss or discard (Barrett & Needham, 1988). Furthermore, hoard deposition is argued to be an indicator of periods of economic growth and recession (Kristiansen, 1998), and might be a more accurate reflection of a struggling or burgeoning economy than raw numbers of axe heads.

Harding (2000:106) believes that given the small scale of most European Bronze Age societies, that "raiding" rather than "institutionalised" warfare was the primary act of aggression. In this way, he suggests, could individual warriors accrue power and prestige within their communities. The roles of individual types of weaponry may have differed from place to place and from society to society; to illustrate this Harding indicates that in Britain, most Bronze Age swords are recovered from bogs and rivers, whilst in Hungary, the majority are found in scrap hoards. This perspective seems to agree with the general understanding of the status of warfare in Britain . Champion (1999) notes that examples of Later Bronze Age arms and armour from southern Britain are highly decorative and elaborate, and evoke a strong sense of power and prestige, and suggests that some design aspects of these pieces might make them unsuitable for

real fighting. Overall, however, the nature and implications of warfare in prehistoric Britain have received scant attention (Sharples, 1991), providing very little basis on which to make generalisations about the causes and consequences of conflict during the Later Bronze Age.

Famine

While there is a reasonable basis for some future resolution concerning the status of warfare in Bronze Age Britain, reconstructing the significance of famine and plague is likely to be tricky, if not outright impossible. The 'appropriateness' of a famine scenario can be assessed based on the understanding of the nature and conditions for the development of famine situations. Rather than a simple causal response of crop failure to some exogenous factor such as climate deterioration, famine embodies a complex sociocultural response to the shortage of food. Several conditions are suggested to indicate vulnerability to famine: dependence on staple crops, high risk in the fluctuation of food sources, absence of social security (*e.g.*, where traditional systems of mutual support have been disrupted) and war (Devereaux, 1993). Famine is not only about the failure of food supplies, but the extreme failure of coping strategies (Devereaux, 1993). The question remains, what were Bronze Age coping strategies and can their failure be demonstrated?

Plague

Plague is also touted as a real consequence of climatic deterioration (Burgess, 1985; 1989; Baillie, 1989). While it is argued that the inability of the archaeologist to identify individual diseases is immaterial (Burgess, 1985), in reality, understanding the vectors and biology of different diseases is crucial to assessing the likelihood of plague. For example, infectious diseases such as small pox and measles require large populations to become epidemic (Ell, 1993). Airborne viruses also require large populations to propagate effectively (Ortner & Theobald, 1993), or the breakdown of biogeographical barriers (Crosby, 1984). Only if a disease is identified can work begin to attempt to uncover the vector of transmission. In general, the adoption of farming probably posed one of the greater health threats to prehistoric humans in terms of disease. With the domestication of animals, humans were exposed to infection from anthrax and

tuberculosis (Stannard, 1993). Breaking up of the soil for tillage would have released spores responsible for fungal infections (Ortner & Theobald, 1993). In general, the proto-urban centres of the early Near East were probably the vulnerable to epidemics, but most likely suffered from persistent low level infections and parasitic illness (Stannard, 1993). Ell (1993:245) argues that there is no evidence supporting disease in the decline of Mediterranean civilisations in the 12th century BC and "...to impose a demographic and disease structure on [prehistory] is folly".

Forest Regeneration

An Indicator of Economic Recession and Settlement Change?

As further support to the low axe-population crisis scenario, Burgess (1985) drew on pollen evidence which he suggested showed a correlation between periods of low axe deposition and forest regeneration (Figure 1.9). Evidence for the regeneration of woodland in pollen diagrams, seen as an increase in the representation of tree type pollen over non-tree type pollen, was for some time equated with the abandonment of agriculture (Berglund, 1969, 1986). This is one half of the so-called "expansion-regression" model used in the interpretation of pollen curves (Berglund, 1969, 1986). Forest disturbance, indicated by the decline in the pollen of trees and a rise in open or disturbed ground taxa including grasses, herbs, cultivated plants and weeds associated with arable or pastoral activities (Behre's (1981) "indicator species") was seen as a purposive clearance of the land for the expansion of agriculture (Iversen, 1941; Berglund, 1969, 1986). Abandonment of agriculture resulted in the re-establishment of the woodland, with the decline of indicator species and rise in tree pollen. The re-establishment of forest cover, apparently at the expense of productive agricultural ground was seen as a symptom of economic stress (Whittle, 1978).

Dependency on such a literal interpretation of the ratio of tree pollen to non-tree pollen has been questioned from several perspectives (Brown, 1997; Göransson, 1988; Edwards, 1993; Whittington & Edwards, 1998; Tipping, 1994). The re-establishment of woodland may be one indicator of the increasing 'marginality' of a site (Whittington & Edwards, 1998). However, the woodland, some argue,

should not be seen as obstacle to agriculture, but an integral part of the economy (Göransson, 1988). If pollen cores are taken from large lakes or bogs, small garden plots in heavily wooded landscapes may go undetected or the re-growth of woodland may filter out the signal of nearby human activity (Edwards, 1981, Edwards & McIntosh, 1988). It has also been argued that the expansion-regression model is inappropriate for interpreting human impacts in mostly treeless areas, such as Caithness in the far north of Scotland (Tipping, 1994).

Elucidating the presence and impact of humans on vegetation has always been an important aspect of pollen analytical research (Dumayne-Peaty, 2001), although its significance in archaeological research design has often been considered, unjustly, somewhat ancillary (Edwards, 1999; Edwards & Whittington, 1994). The application of palynology in cultural contexts has been addressed in a number of important recent contributions by Birks *et al.* (1988), Berglund *et al* (1986) and a series of publications Edwards (1979, 1982, 1988, 1993) to name only a few. Many developments have occurred in the statistical handling of pollen data, sampling strategies, understanding of pollen productivity and dispersal characteristics, relationships between pollen and plant abundance (Hjelle, 1998), the detection of agricultural activities in open landscapes and landscape openness (*eg.*, Broström *et al*, 1998; Sugita *et al.*, 1999) and how agricultural floras have changed through time with advancements in agricultural technology (Hillman, 1991). These advancements have refined and enhanced our understanding of the ways in which people engaged in altering and manipulating their environments (Dumayne-Peaty, 2001).

In terms of Burgess' use of pollen data as support for the abandonment of the uplands, it appears that rather than simply an unsophisticated handling of pollen data, that Burgess may simply been wrong. Young (2000) and Tipping (1994) indicate that, contrary to arguments that there was significant forest regeneration between 1200 and 900 BC (*in* Burgess, 1985), pollen records from many sites, upland and lowland, in northern England and parts of Scotland reflect continued human activity. In fact, at the two sites where large scale regeneration supposedly took place (*in* Burgess, 1985), Camp Hill and Steng Moss (Davies & Turner, 1979), a visit to the original data shows little evidence for any larges scale

clearances prior to the Bronze Age at either location, but at Steng Moss a brief episode of clearance is recorded between 1000 and 850 cal BC (Young, 2000). Furthermore, at Camp Hill continuous small-scale land-use was recorded between 1560 and 160 cal BC, although it was suggested that pressure on the land was somewhat diminished between 1160 and 720 cal BC (Davies & Turner, 1979). Young (2000) also highlights palaeoecological reconstructions from Dumfriesshire (Tipping, 1995a, 1995b; 1997), Black Loch, Fife (Edwards & Whittington, 1994), Braedroddoch Loch, Aberdeenshire (Edwards & Rowntree, 1980) and Carn Dubh, Perthshire at a site located at *ca.* 400m OD (Tipping, 1995a) where human activities are sustained throughout the Later Bronze Age.

Radiocarbon Dating: Evidence of Absence or Absence of Evidence?

Chronology and Settlement Change

The other main line of evidence used is a lack of radiocarbon dated settlements which can be ascribed to the late second millennium BC. (Burgess, 1980), especially in the uplands of the Anglo-Scottish Borders (1985). This line of reasoning has been thoroughly attacked by Young & Simmonds (1995) who point out that the use of radiocarbon dates was selective and not a true reflection of radiocarbon dated occupation horizons. Subsequently, it has been argued that the chronology of settlement from the Borders region reflects continuity, not abandonment (Young, 2000; Young & Simmonds, 1995, 2001. Barber (1990) argues for a widespread abandonment of upland Scotland during later prehistory on the grounds that there are no burnt mounds dating to the 12th century. Despite mounting evidence to the contrary, Barber (1997) contends that there is a dearth of radiocarbon dated settlements, particularly from upland sites and other marginal areas, such as north facing slopes between *ca.* 1000 uncal BC and 500 uncal BC (1300-600 cal BC).

There are some fundamental issues in the ways in which archaeologists use radiocarbon dating and the precision and accuracy they confer upon dates: "Archaeologists' habitual preference for 'dates' over 'ages' seems to derive from our socialisation to sidereal years as enshrined in calendars. This cultural preference is incompatible with the imprecision inherent in most archaeological

chronometers." (Dincauze, 2000:86). Archaeologists have been roundly criticised for demanding a precision in dating that simply does not exist outside dendrochronology (Baillie, 1989, 1990; Buckland *et al.*, 1997) in order to 'have their catastrophes' (Baillie, 1989:117). While dendrochronology can boast annual precision, and ice cores, interannual to decadal, the materials available to archaeologists for dating usually offer substantially less precision. Radiocarbon dates with their often wide range ranges are in danger of either 'sucking in' events which lie close to the radiocarbon error margins and have been dated by more precise methods, *eg.*, dendrochronology. Alternatively, radiocarbon dates can 'smear' a discrete event across a century or more (Baillie, 1990). This has serious implications for establishing the cause and effect relationships demanded by a Later Bronze Age catastrophe scenario.

Radiocarbon ages are *not* calendar ages, thus, particularly, from an archaeological stand-point, *calibration is essential* (Brauzinas, 1994). Highly accurate records of past fluctuations in atmospheric ^{14}C have been obtained using known age samples of wood or corals to create 'calibration curves' extending through the Holocene (Pilcher, 1991,1993; Taylor, 2001 *for reviews*; Stuiver & Pearson, 1993; Pearson & Stuiver, 1986; Stuiver & Reimer, 1993). In sections of the curve, 'plateaux' are apparent. where all calendar ages which fall into this range appear to be the same because of low variations in the production of atmospheric ^{14}C, preventing any sort of precision in correlating records during this period. Of relevance to this thesis is the plateau between 800-400 BC. The 'de Vries effect' or rapid, short term changes in atmospheric ^{14}C also affect the precision with which radiocarbon age estimations can be calibrated into calendar dates (Taylor, 2001). There are certain difficulties which arise from conventions of quoting radiocarbon ages in archaeological publications. Although many journals now require the publication of calibrated date (cal BP and cal BC/AD) (see also Dalland & McCullagh, 1998; Taylor, 2001), current and past literature is littered with mixtures of 'bp', 'bc/ad' denoting uncalibrated or in the case of 'bc/ad' historical dates and the calibrated 'cal BP' or 'cal BC/AD'.

The influences of archaeological site formation processes can also affect the accuracy of 'dates' (Dean, 1978; Stein, 1992; Taylor, 1987). Taylor (1987)

stresses that it is difficult to evaluate directly the various factors that could influence the accuracy of a radiocarbon 'date', and that little reliance should be placed on the ability of a single assay to provide a reliable 'date' for an object, feature, or stratigraphic unit. Effort has been made to refer to 'dates' in the presentation and discussion of results in this thesis by the more accurate terms of 'age estimates' or 'age ranges', and where ever possible 2σ age ranges are quoted because ^{14}C analyses only provide a range with which the true age of the material has a statistical certainty of falling (Dean, 1978; Dincauze, 2000; Taylor, 1987).

The laying down of a tree ring, for instance, cannot be argued to be directly associated with a behavioural event such as leaving a house for the final time (Taylor, 1987). A radiocarbon age does not provide a 'date' for a site, building, grave or level, the 'date' is the 'date' of the sample and it is the archaeologist's task to assess to the relationships between the sample and the place it came from and the target date. This is particularly crucial when it comes to 'accepting' or 'rejecting' radiocarbon ages. They should never be rejected because they do not fit 'expected chronologies', but, more correctly, they should be assessed on grounds of stratigraphic integrity and likely sources of contamination (Barker, 1993; Pilcher, 1993; Schiffer, 1987; Taylor, 1987).

Another issue is the great deal of emphasis placed on apparent cultural disjunctions between, for example the 'Penard period' and 'Ewart Park' or the 'Bronze Age' and the 'Iron Age'. Major social and economic changes do not necessarily take place at the arbitrarily created boundaries of the Three Age system, but occur sometime after, thus the Late Neolithic and Early Bronze age form a sort of continuum, as does the Later Bronze Age and Early Iron Age (*cf.* Rowlands, 1984). To adapt the Urnfield example Kristiansen (1998) uses, to the context of this research, the Penard Period (1200-900 BC) did not arise spontaneously out of itself, but is a result of processes which began in the Knighton Heath period (1400-1200 BC), or possibly even earlier. Furthermore, like the 'Wessex culture', these cultural traditions are in all likelihood geographically de-limited within the British Isles and the same historical processes may not be discernible or even need have existed in northern Britain (*cf.* Bevan, 1999; Harding, 2000; Young, 2000).

Setting the Parameters: the Concept of 'Marginality' in Settlement Archaeology

The notion of marginality plays a central role in archaeological explanations of settlement change and abandonment. Recently, it has been argued that archaeologists, (and perhaps a few palaeoecologists) have relied on environmentally determined perspectives of what constitutes the 'margin' (Young, 2000; Young & Simmonds, 2001). The term marginal — 'marginality', 'on the margins', etc. — has become so widely accepted and integrated into archaeological thought in Britain that it is often applied with little consideration for the implications — a sort of "fuzzy catchall" (Coles & Mills, 1998:ix). The following discussion will consider the origins, applications, implications and future of the concept of marginality in archaeological interpretation.

Parry's Hypothesis

> "If the probability of stress from climatic changes exists in relation to agricultural systems which have the support of modern technology, should not the possibility of more serious stress on early and more primitive agricultural systems deserve...investigation?"
>
> Martin L. Parry *Climate, Agriculture and Settlement* (1978)

Fox's *The Personality of Britain* (1932) is partially, if not wholly, responsible for the persistent division of Britain's landscape into two opposed and mutually exclusive entities: the fertile productive Lowland and the harsh, marginal Upland (Coles & Mills, 1998). Marginality is treated as an inherent characteristic of certain landscapes, rather than an attribute that might be conferred by cultural preferences, practices or prejudices. The work of the historical geographer Martin Parry work permitted this largely aesthetic ideal of a 'marginal landscape' to be quantified and systematised. His PhD thesis (Parry, 1973) and the development of its subject matter in subsequent publications has made an enduring contribution to both geographical and archaeological thought and has provided a fruitful source of ideas and debate. Risk analysis, one of his primary approaches, introduced a new and exciting level of complexity in evaluating the relationship between humans and the environment.

The timing of Parry's formulation of the relationships between climate, agriculture and settlement followed in the wake of the geography's 'quantitative revolution' of the 1950s, which culminated in the 1970s, which recognised that the qualitative approach to interpreting proxy climate data was no longer sufficient (Haines-Young & Petch, 1996). Parry's investigation into climate-human interactions set an agenda which archaeologists, particularly Burgess (1985, 1989), eagerly sought to adopt for their own purposes. His primary contribution to debates on the impact of climate change in prehistory has been the adoption of an environmentally based conceptualisation of marginality (Young & Simmonds, 2001). Parry chastised historians for taking a short view of history, for ascribing more value to short term changes related to social, political and other economic factors, and for failing to grasp the importance of climate in human experience. Parry was interested primarily in the long term — secular shifts in climate change such as the Little Ice Age — impact of climate on agriculture and settlement. He assumed that the perceived risk associated with the frequency of crop failure was the determining factor in the decision making process of farmers. To Parry, altitude and temperature were the only effective control on the limits of arable agriculture. From these variables, it was argued that the risk and frequency of crop failure could be estimated to formulate critical thresholds at which farmers would be forced to 'give up' and abandon their land.

Subsequently, Tipping (1998) tested Parry's Hypothesis in relation to Little Ice Age cultivation in the Cheviot Hills of southern Scotland with evidence from the pollen record. The results indicated that growth of cereals continued at or above Parry's 'critical thresholds' at period when abandonment should have occurred. Climate was rejected as a controlling factor in agricultural decision-making in the Cheviot's. The prolonged and episodic nature of the contraction of arable agriculture from the Cheviot uplands led Tipping to the conclusion that socio-cultural factors were more of an influence than environmental change. Both Tipping (1998) and Young and Simmonds (2001) have criticised the Lammermuir study for its imprecise dating of the settlements being investigated. A series of publications from different perspectives (Duncan, 1992; Tipping, 1998; Young, 2000; Young & Simmonds, 1995, 2001) called into question the validity of Parry's definition of marginality.

The degree-day concept, which was used by Parry (1978) in his assessment of the Lammermuirs Hills in southeast Scotland, has several other short comings. Years with warm springs and cool summers or cold springs and hot summers are not differentiable; they make no allowances for unfavourably hot temperatures or diurnal temperature ranges; and they neglect specific temperature values or trends that may be critical at specific developmental stages of a particular type of crop (Michaelowa, 2001). Changes in temperature are only important in extremes, and the general rule of thumb is that as long as mean monthly temperatures exceed 6°C, conditions will be adequate for the growth of some types of crops (Bayliss-Smith, 1992; Whittle, 1981).

'Core and Periphery' Concepts as a Key to Understanding Settlement Change

The concept of marginality forged by Parry and applied by Burgess has evolved into a somewhat more sophisticated discussion of settlement 'cores' and 'peripheries' (Cowley, 1998; Halliday, 1993; Tipping & McCullagh, 1998). Core areas reflect the most favourable range of attributes of soils, vegetation, aspect, drainage altitude and water supply. Core areas are settled preferentially and settlement in these areas tends to persist, successive episodes erasing or partly eradicating evidence of earlier settlement and land-use. Peripheries, on the other hand, might be seen as a euphemism for 'marginal'; these areas reflect the least favourable range of attributes, are settled last, and then only intermittently. The strength of the core-periphery model is the premise that landscapes are not uniform, but constructed out what are characterised as a 'nested hierarchy of ecological niches', and that people would have selectively and actively engaged with these different niches (Halliday, 1993).

However, this concept of core and periphery relies solely on the relationship between people and ecological attributes of places (the 'personality of place'). The environment retains its function as a limiting factor in human choice and experience. Places are distilled into a set of apparently neutral physical attributes and come to simply embody an ideal of what a core or periphery *ought* to be. The people who live in these places are reduced to passive agents, controlled by external causal and deterministic elements (Barnes & Curry, 1983). Archaeologists

and palaeoecologists construct perspectives of a landscape based on observations of it 'natural' attributes: soils which might be cultivated or where livestock might be grazed, the distribution of visible structures, altitude, modern day vegetation and reconstructions etc., and because of empirical claims of objectivity, it is transformed into an idealised landscape of the past.

Core and periphery also fails to address implications of territoriality and power that core-periphery relationships entail. Core-periphery models, or centre-periphery, describe relationships between 'centres' which control the manufacturing and distribution of goods by dominating or otherwise exploiting 'peripheries' which produce or have direct access to raw materials (Eckholm, 1980; Eckholm & Friedman, 1982). The relationship can be characterised by various degrees of population density and levels of complexity (Chase-Dunn & Hall, 1991), but the main implication is that the experiences of those who live in the peripheries are, to a great extent, determined or controlled by those living in the core (Lillios, 1996). Following Fox's model, lowlands, it seems to be assumed, would have been the controlling force, but as Young and Simmonds (2001) have pointed out, much of the ambiguity about what defines a core and how it relates to other aspects of social and economic activity must be dealt with before margins can be delineated.

Moving Forward: Developing New Concepts of Marginality and Settlement Change

Increasing emphasis is being placed on integrating the 'social' and the 'environmental' in order to better understand marginality and its significance in every day human existence (Coles & Mills, 1998; Young, 2000; Young & Simmonds, 1995, 2001). The construction of a selective hierarchy of different types of 'marginality', *ie.*, socio-political/economic/ecological (Blaikie & Brookfield, 1987), should be avoided because it masks the complex discourses between different spheres of the social and natural environment that together constitute the "total environment" which people inhabit (Young, 2000:17; also Barrett, 1999). Marginality is not just a function of the physical attributes of a landscape, but is intimately linked to the way people perceive and manipulate the landscape (Coles & Mills, 1998; McCullagh & Tipping, 1998). Moreover, human

communities do not exist in isolation. Interactions between and among communities through trade, conflict and co-operation will also play a defining role in marginality (Young & Simmonds, 1995). Absenting people from the record, or reducing them to neutral agents at the mercy of a hostile world, denies the power of culture whereby humans can manipulate language, symbols, technology, tradition, innovation to adapt to a changing world: "...[i]ndividual cultures are cognitive heritages from the past that provide guidance for everyday life, constitute the basis for coping with changing conditions and may actively encourage resistance to change" (Trigger, 1995).

'Marginal' has negative connotations; there is an implicit assumption that the 'margin' is a bad place to be, a place of stagnation, of backwardness, they have a tendency to be 'inward looking' (*eg.*,. Tipping & McCullagh, 1998). We may think of politically marginal groups whose access to power is limited, or economically marginal groups who perhaps excluded from certain markets or other benefits of society. Others argue that this is a one dimensional and inaccurate view of the margins. Mathews (1995) suggests that change can begin in the margins, not the core, and be mediated upwards and outwards through society. Physical boundaries can be dynamic areas where the exchange of information and goods, taking place in the context of large regional exchange networks, can promote the development of separate cultural identities among these specialised settlements which control the flow of trade (Kristiansen, 1998). No matter how much power a core may have, they still need the raw materials supplied by the periphery whose ability to protect its control over these assets may supply a valuable tool for power negotiations.

Settlement Change and the Conundrum of Settlement Abandonment

Identifying the apparently permanent disuse of structures has been considered sufficient evidence of the failure of prehistoric agricultural settlements as a result of adverse environmental conditions (*eg.*, Barber, 1997; Cowley, 1998; Grattan & Gilbertson, 1994). However, abandonment is not an "either/or phenomenon", it is one end of spectrum in which permanent residence is the other (David & Kramer, 2001:111) (Figure 1.10). Abandonment takes place at a variety of different scales

and incorporates a variety of different processes; in order to interpret sites accurately, archaeologists must understand these processes (Cameron, 1996; Schiffer, 1987). Through the detailed analysis of ethnographic and archaeological material, site formation processes and artefact assemblages, it has become possible in certain situations, to distinguish different types of abandonment strategies such as, gradual, permanent (whether as a response to a 'catastrophe' or otherwise), episodic, seasonal, punctuated and agricultural and the stimulus behind them (*cf.* Cameron & Tonka, 1996; Nelson, 2000).

In a recent assessment of abandonment studies from around the globe, Stevenson and Tomka (1996:193) warned that "...abandonment studies for their own sake are likely to be...unrewarding...and even misleading if we do not use our knowledge to address larger theoretical or cultural questions." The emphasis on outcomes, in this case the apparent desertion of upland 'marginal' landscapes in Britain, and specifically, Scotland, as a response to climate change, has led to inferences about abandonment processes that, it will be argued, have not been adequately investigated or measured with the archaeological evidence. Many, if not all, of the archaeological interpretations of settlement change in Scotland overlook the fact that abandonment is not an aberration it is "... *a normal process of settlement change*." (Cameron 1996:3, italics added).

Research has helped in identifying some of the factors, such as (delayed) curation of objects, caching, dismantling of structures, interruptions of discard patterns, scavaging and dumping, which can be associated with different types of abandonment processes (reviews by Cameron & Tonka, 1996; David & Kramer, 2001; Schiffer, 1987). For example, it has been found that in many cases not only are fewer artefacts associated with permanently abandoned residences than those where return is expected, but that the frequency of expedient items was greater than craft or other manufactured items (Tomka, 1996). Work by Graham (1996) indicates that during episodes of punctuated (temporary) abandonment, objects and tools commonly used at that site are stored in activity areas, but personal belongings and costly objects are never found in abandonment contexts. When sites are permanently abandoned, however, it was observed that the spatial boundaries of activity areas, sheltered areas and rubbish tips broke down and

objects were discarded regardless of previous behaviour. In other cases, dumping in unoccupied structures may be a more likely occurrence in areas of nucleated or urban settlement (David & Kramer, 2001).

When a site or structure does become permanently abandoned, identifying and understanding the processes which influenced its incorporation into the archaeological record is critical to the interpretation of the complex arrangement of cultural and environmental materials (Schiffer, 1987). Microbial attack, cryoturbation, fluvial processes and bioturbation can effect the orientation, preservation and stratigraphic relationships of artefacts, as well as erosion (Wood & Johnson, 1978). Both structures and objects are vulnerable to scavaging behaviour and the identification of different behaviours potentially provides useful information about social context of abandoned structures. (Schiffer, 1987).

The literature addressing the issue of Later Bronze Age settlement/abandonment in Scotland, with a few notable exceptions (*eg.*, Carter, 1993; McCullagh & Tipping, 1998) shows a striking lack of consideration of the concerns, limitations and implications of methodological approaches in archaeological excavation and interpretation. Particularly now in archaeology, with the increasingly inter-disciplinary nature of research, there is a need to critically assess the validity and necessity of approaches and methods (Dincauze, 2000; Jones, 2002; Wobst, 1997). Methods need to be chosen which are appropriate to the questions being asked, because "...the study of an archaeological site by excavation is an unrepeatable experiment" (Barker, 1993:13). However, designing and implementing such research strategies is by no means a straightforward task; reconstructing occupation histories is one of the most difficult and challenging aspects of archaeological research and the techniques are still under debate (Schiffer, 1987).

Ethnographic and archaeological research from other parts of the world has contributed a significant amount of information concerning the causes of abandonment, abandonment as a process or land use strategy; the types of artefact patterning associated with different scales and processes of abandonment; and understanding the occupation histories of individual sites, settlements and regions (Stevenson & Tomka, 1996; Schiffer,1987). Many current methods used in

excavating and recording archaeological data do not adequately allow for the reconstruction of human activities at sites (Schiffer, 1987; Wobst, 1997). One means of redressing this is by identifying the processes which influence the formation of archaeological sites; a more comprehensive understanding of taphonomic processes, ethnoarchaeology and experimental archaeology, will help archaeologists to understand the past agencies which gave rise to the complex arrangement of cultural and environmental material (David & Kramer, 2001; Schiffer, 1987). The issue of settlement change at the close of the Bronze Age then becomes not one of whether or not settlements were abandoned, but *how* and *why* individual sites and settlements were abandoned and to assess whether or not the abandonment of entire regions and the mechanisms behind such an abandonment can be identified adequately.

Rationale for this Investigation

Several important conclusions can be drawn from this analysis of the previous research that have laid the foundation for my investigation into climate-human interactions in the Strath of Kildonan. It was demonstrated above that archaeological and palaeoenvironmental records have been used, and in some cases, modified, in order to garner support for a Later Bronze Age settlement catastrophe. As such, the theory has been formulated based on "...equations [which] seem convincing because of an unconscious Procrustean truncation which lops of those part of the phenomenon that do not fit" (Sherratt, 1997: 277). This is most aptly illustrated by the 'selective use' of radiocarbon chronologies and forest regeneration employed by Burgess (1985, 1989), and later refuted by, for example, Young (2000) and Young and Simmonds (1995, 2001). Other premises on which the theory rests, such as population crises caused by famine, plague and warfare are rejected because they lack testability. These phenomena are required to be taken on faith, on scholarly opinion alone because they cannot be investigated with the available archaeological data. Until an approach is formulated which might usefully and reliably measure and evaluate the significance of population crises in prehistory, they must be excluded from the discussion.

The argument has been proposed that monocausal explanations for archaeological abandonment are not satisfactory because, in part, rarely were landscapes so uniform ecologically or so sociopolitically integrated that a single catastrophic event would affect a whole region to the extent that all of the settlements would have been abandoned (Lillios, 1996). The challenge in archaeology is to resolve the appropriate scales at which interactions between environment and society can be investigated. A recent publication by Jones (2002) has explored the problem of scale in archaeology. He makes the point that if archaeological research attends only to the 'macroscale' — the culture history approach — interpretations will only be effective at this scale. 'Microscale' — context specific — investigations, however, can be scaled up to help explain process occurring at large scales.

The formulation of a Later Bronze Age catastrophe has its roots in the culture-history approach, where cultural traditions (*eg.*, Beaker, Penard, Bronze Age) often replace people (or human agency) in the construction of archaeological interpretation (*cf.* Jones, 2002). This is highlighted by Harding's (2001) criticism that the understanding of later prehistory in northern Britain has been framed in the Wessex dominated cultural traditions of southern Britain, which have few or no parallels in northern Britain. Approaches need to be developed which address and improve our understanding of both the social and ecological aspects of climate, settlement and agriculture. The re-evaluation of later prehistoric settlement in the Anglo-Scottish Borders (Young, 2001; Young & Simmonds, 1995, 2000) has achieved this to some extent, with the implication that investigations into the relationship between humans and their environment is context specific.

The theory of a Later Bronze Age catastrophe has never been investigated substantively or methodologically against palaeoclimatic or archaeological data. Data have often been collected and interpreted in retrospect (*eg.* Burgess, 1985; Young, 2001; Young & Simmonds, 1995, 2000) or the interpretations have been pulled 'off the peg' for excavation reports This investigation is the first to strategically implement methods of palaeoecological and proxy climate reconstruction to assess the potential impact of climate change on human communities. The field area, the Strath of Kildonan, Sutherland in the far north of Scotland (Figure 1.11) was chosen on two important counts. Firstly, it has been

argued that the Strath of Kildonan was abandoned in the 12th century BC because of climate deterioration and the eruption of the Hekla volcano (Barber, 1997; Grattan & Gilbertson, 1994; Grattan & Sadler, 2001). Secondly, Scotland's location in the North Atlantic (Figure 1.12; Figure 2.1) means that it is sensitive to re-organisations in climate involving both the ocean and atmosphere.

The palaeoecological approach adopted here, using sediment cores extracted from peat bogs, has several distinct advantages over other potential approaches. Firstly, dateable material is produced *in situ*, and it is possible to date directly horizons of interest, avoiding many problems associated with taphonomy in archaeological excavation. Secondly, it has been demonstrated that pollen analysis is a powerful tool for measuring continuously vegetation changes associated with particular occupation sites through time, whereas archaeological excavations may only provide individual 'snap-shots' in time (Whittington & Edwards , 1994; Tipping, 1994). The combination of pollen data sets, microscopic charcoal curves and mineral content can be used to infer the impact of humans on vegetation structure in a landscape over long periods of time, and as such provides an excellent proxy indicator of human settlement and agricultural activities. Lastly, as mentioned above, peat bogs are valuable archives of proxy climate data. Reconstructions of past climate variability obtained through peat stratigraphic studies can be studied in parallel with records of human impacts obtained from the pollen data.

The investigation will use the evidence from the peat and pollen stratigraphic records to evaluate the potential relationship between land use change, inferred settlement abandonment and evidence for palaeoclimatic change. Tephrochronology is used to both help constrain the palaeoecological record, as well as being evaluated as a potential agent of environmental change and stimulus for long term settlement abandonment and vegetation change. Processes of settlement abandonment, occupation histories and some types of coping strategies cannot be directly inferred from the palaeoenvironmental techniques employed here. However, the methodological issues relating to the study of human-environment interactions discussed above are used as a basis for re-evaluating the extant archaeological evidence used to support the Later Bronze Age catastrophe

in the Strath of Kildonan. Although the primary themes are issues of climate and settlement change during the Later Bronze Age, it is undertaken in the context of an integrative, historical ecological approach which will compare, contrast and evaluate the wider issues in the relationships between climate and culture to the Iron Age and the medieval and post-medieval periods.



Figure 1.1. The coaxial field systems of Holne Moor, Dartmoor.

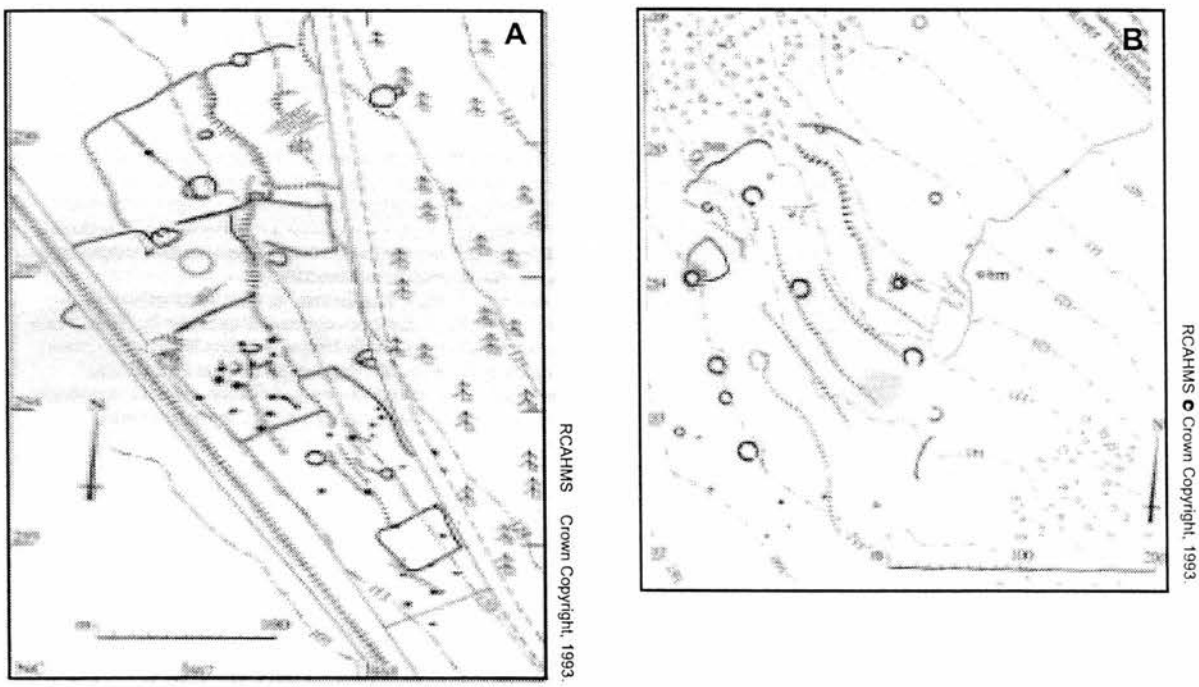


Figure 1.2. Field systems in northern Scotland. Although not reflecting the scale of organisation reflected by the Holen Moor settlements depitcted in Figure 1.1, there is still tremendous variation to be seem in the organisation of settlements. These two settlements and their attendant field systems are both located in the Strath of Kildonan (Figure 1.11). The settlement in drawing A is located at the foot of Kinbrace Hill, whilst drawing B illustrates a settlement just across the Helmsdale River, at Cnon Dal Cairn ('Hill of the Cairns') (Figure 1.11).

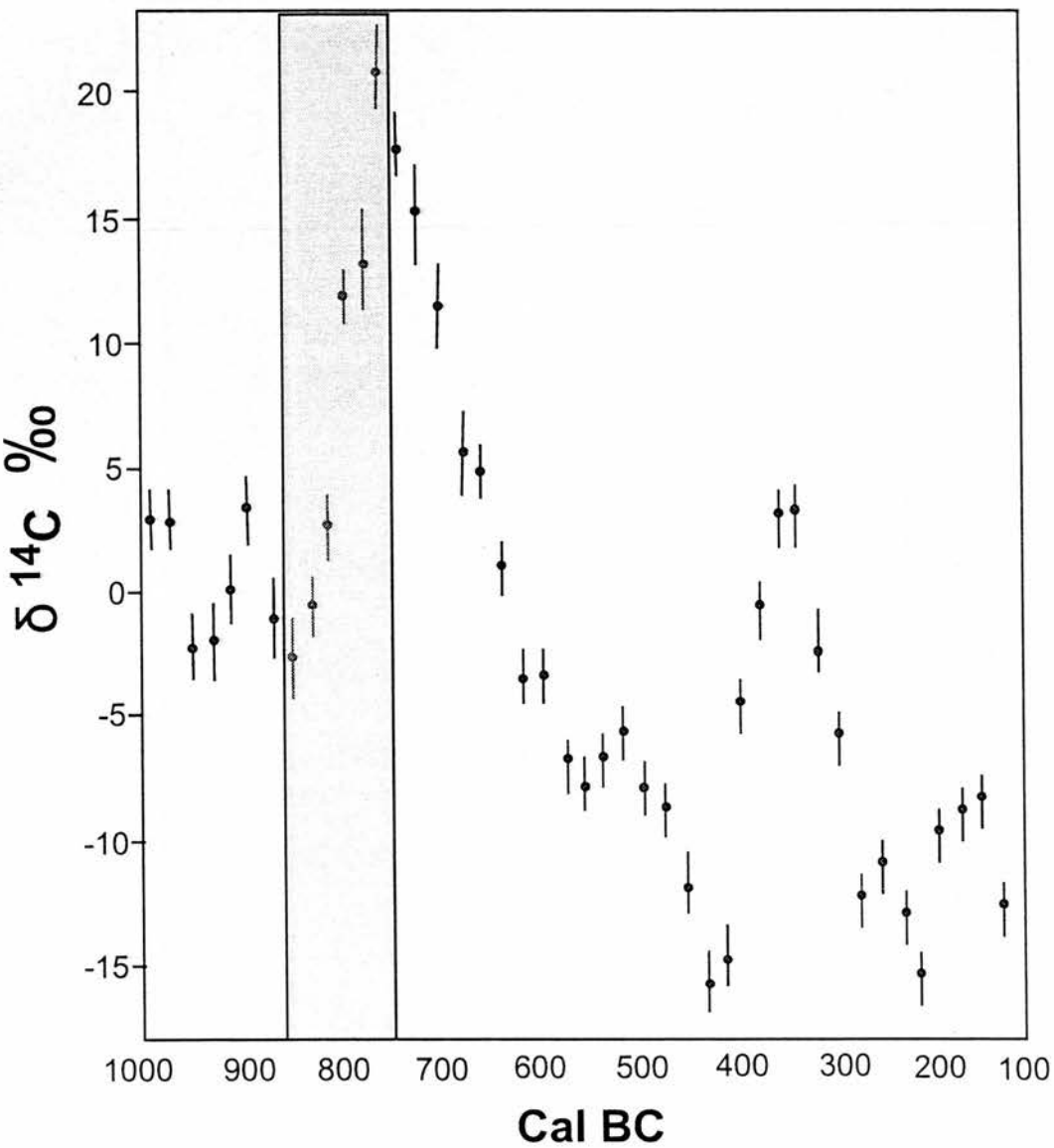


Figure 1.3. The radiocarbon calibration curve highlighting the rise in 14C between 850 and 760 cal BC (Redrawn from van Geel & Renssen,1998). The second rise, at around 400 cal BC, did not result in climate change and social catastrophe, "...presumably because thresholds were not passed again" (p. 23). These thresholds and the processes by which they are passed are not described.

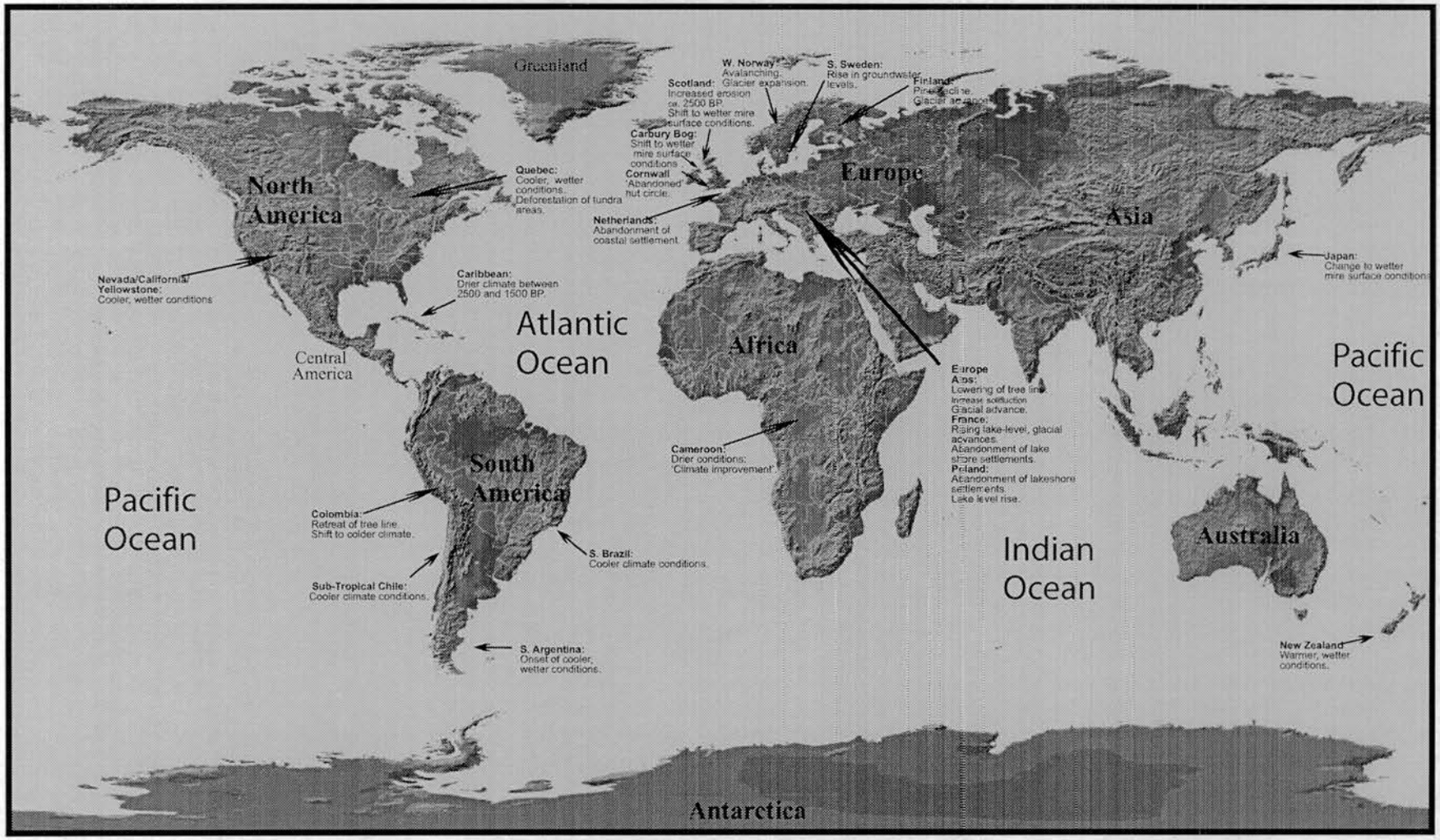


Figure 1.4. A Global Scale Catastrophe. This map highlights the location of the various archaeological and palaeoclimatic evidence used to argue for a global climate deterioration and catastrophe ca. 2,650 cal BP (850 cal BC). The proposed global scale expression of this abrupt and brief oscillation in climate (ca. 150 years) and the uniform responses suggested across a wide variety of cultural and geographical contexts raises some key issues concerning our understanding of the spatial and temporal scales of climate change and their conjunction with human experience. References pertaining to the individual investigations pointed out above are available in the original publication by van Geel & Renssen, 1998.

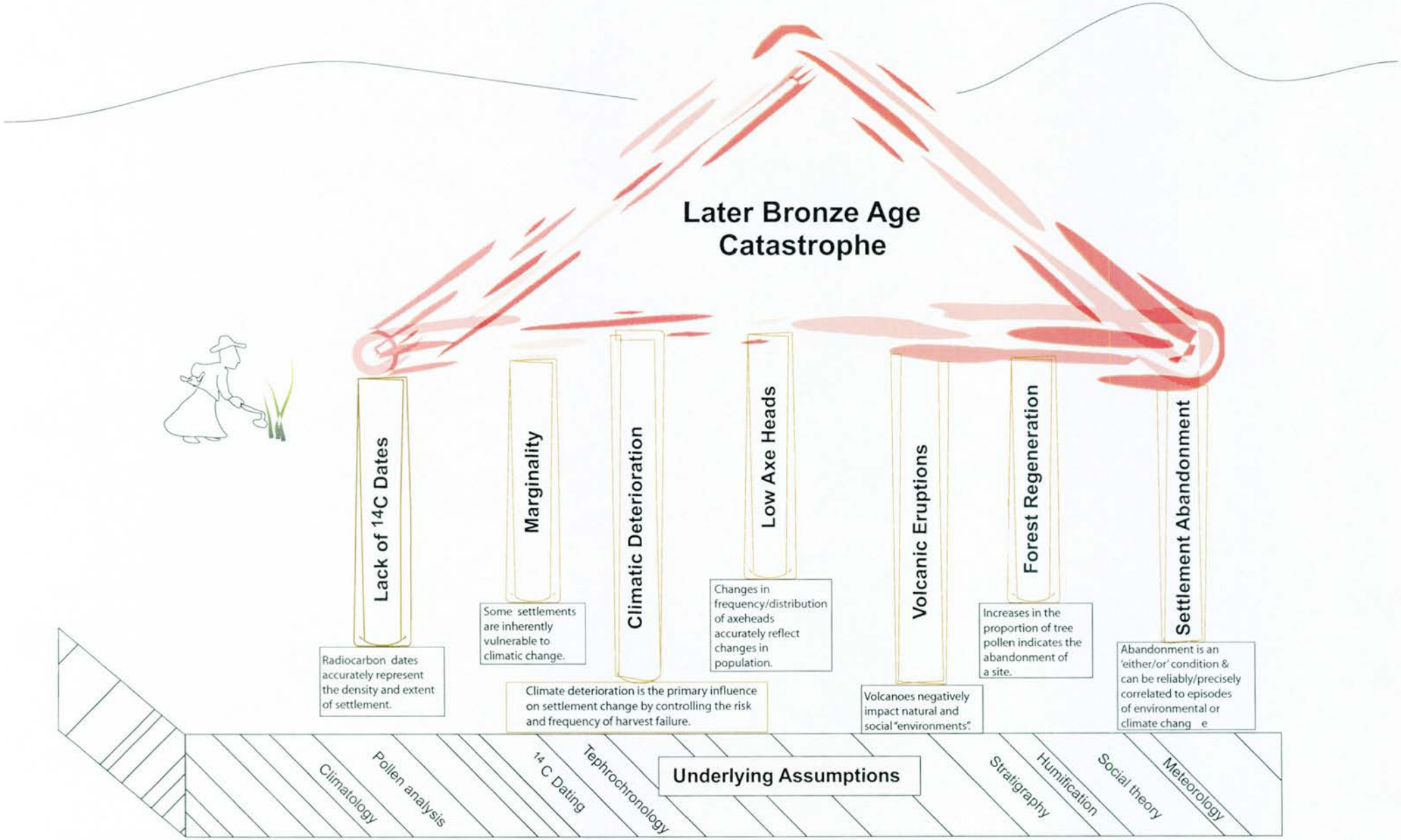


Figure 1.5 The Later Bronze Age Catastrophe

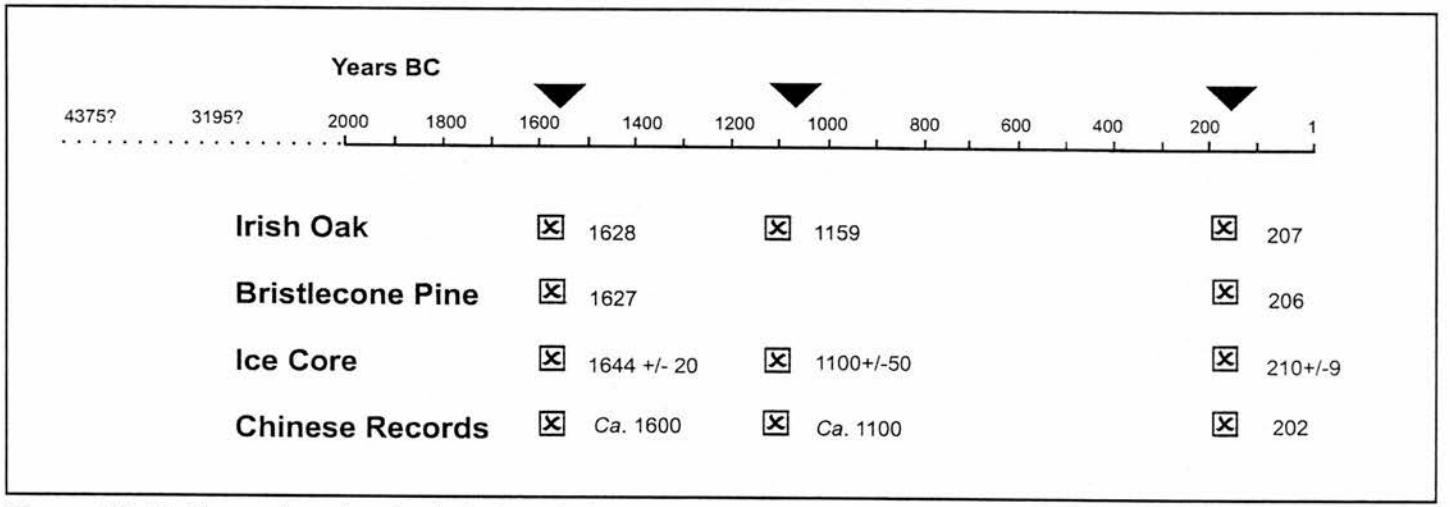


Figure 1.6. Evidence for volcanically induced climate perturbations from tree rings. The GISP2 ice core and historical documents. Redrawn from Baillie, 1989.

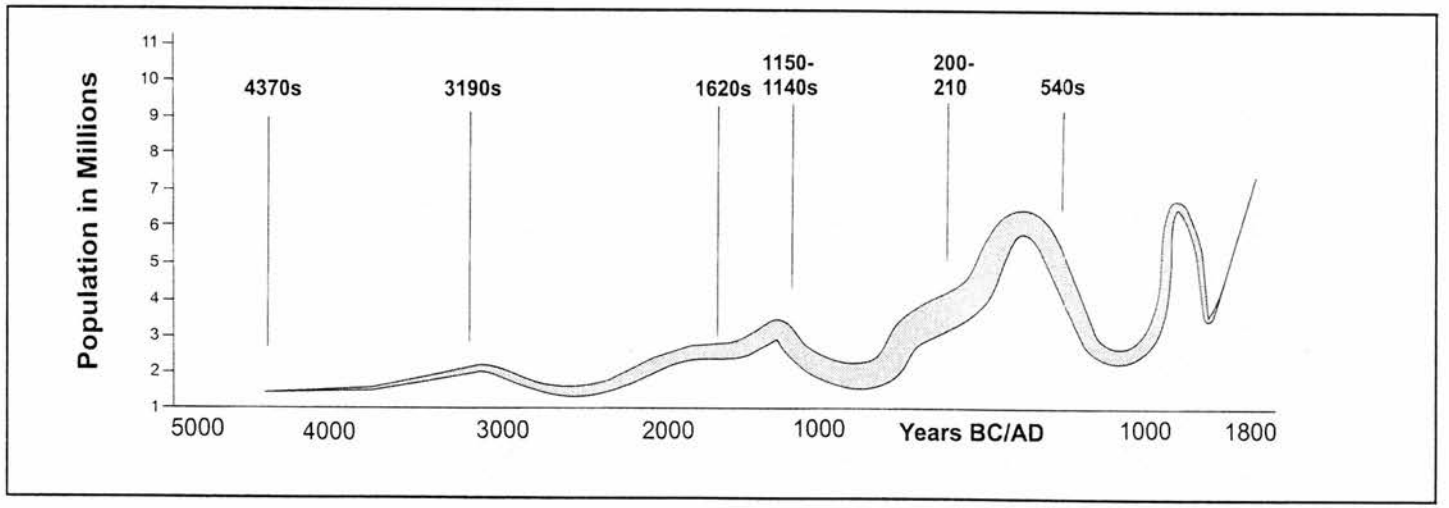


Figure 1.7. Volcanic eruptions and putative population crises in Britain since 5000 BC. Redrawn from Burgess, 1989.

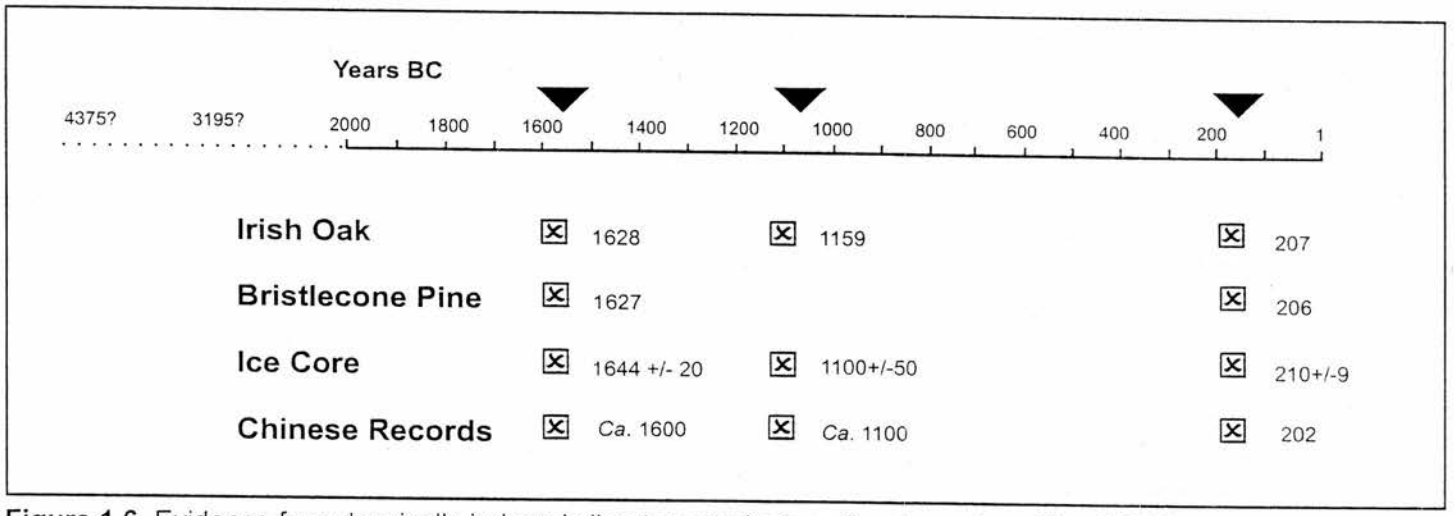


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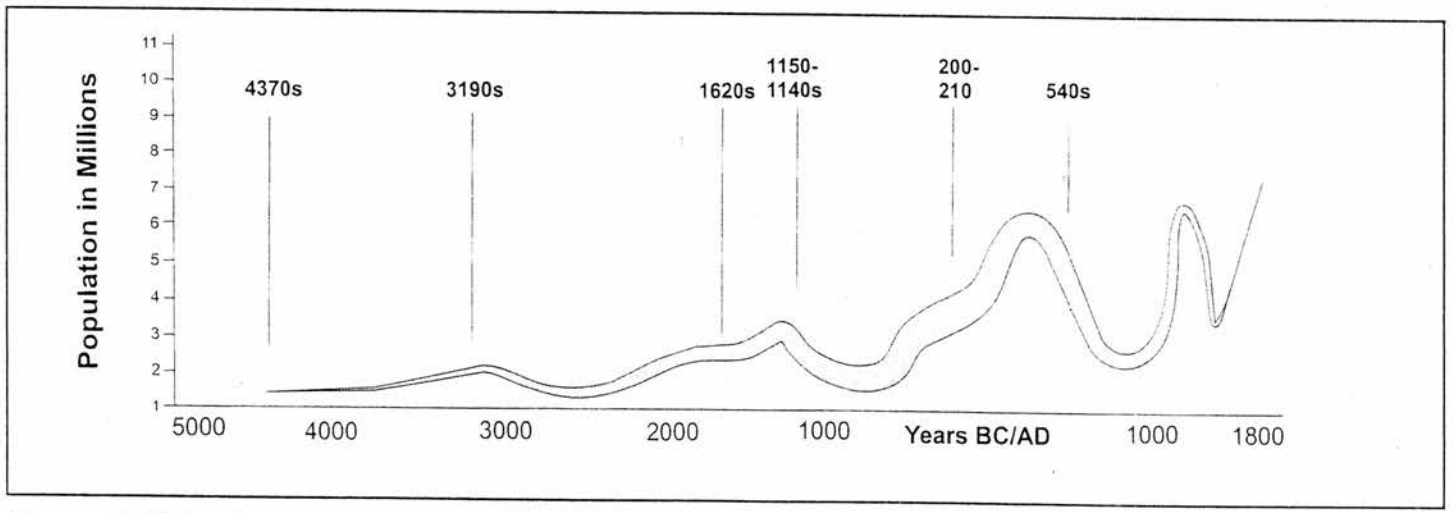


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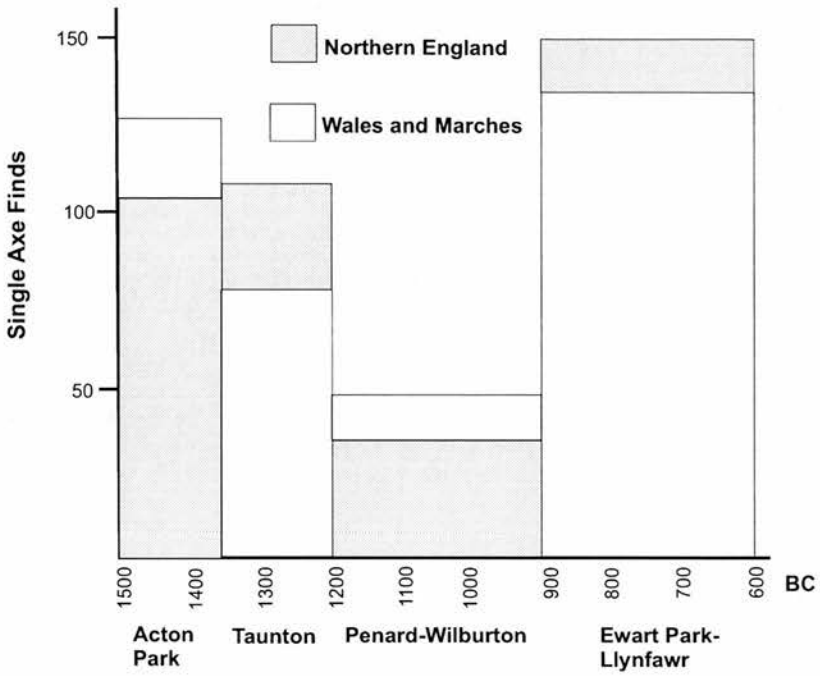


Figure 1.8. Single axe finds plotted against metal-working traditions after Burgess 1985. He suggests the the traditional view of continually rising metal supplies during the Bronze Age is incorrect and that slump in finds of axes belonging to the Penard Wilburton phase (1200-900 BC) represents a slump in population.

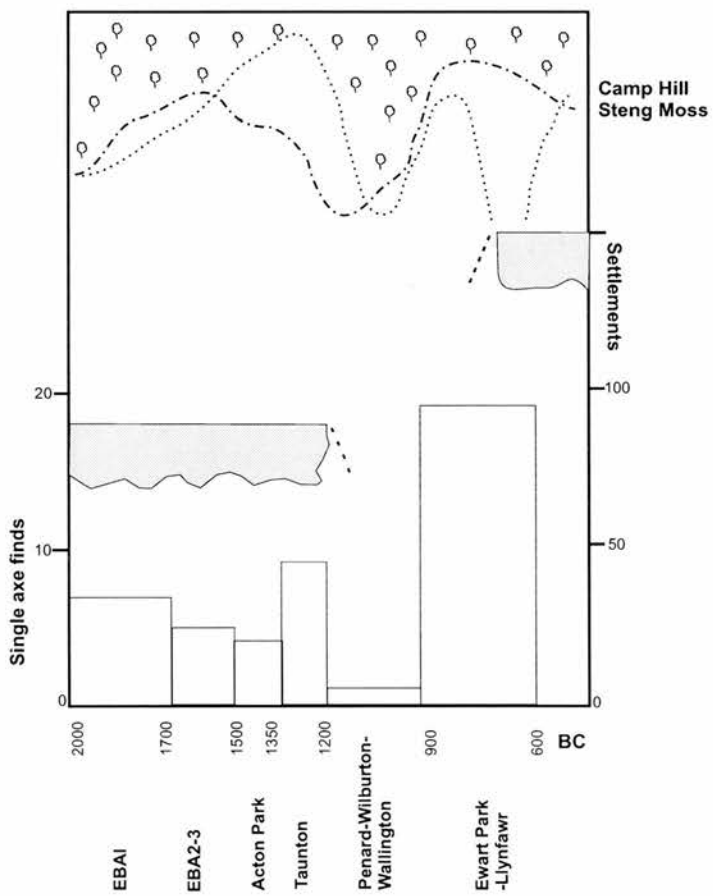


Figure 1.9. Single axe heads, dated upland settlements and the apparent forest regeneration recorded in pollen diagrams from two sites in Northumberland, England (Turner & Davies, 1979). Redrawn from Burgess, 1985

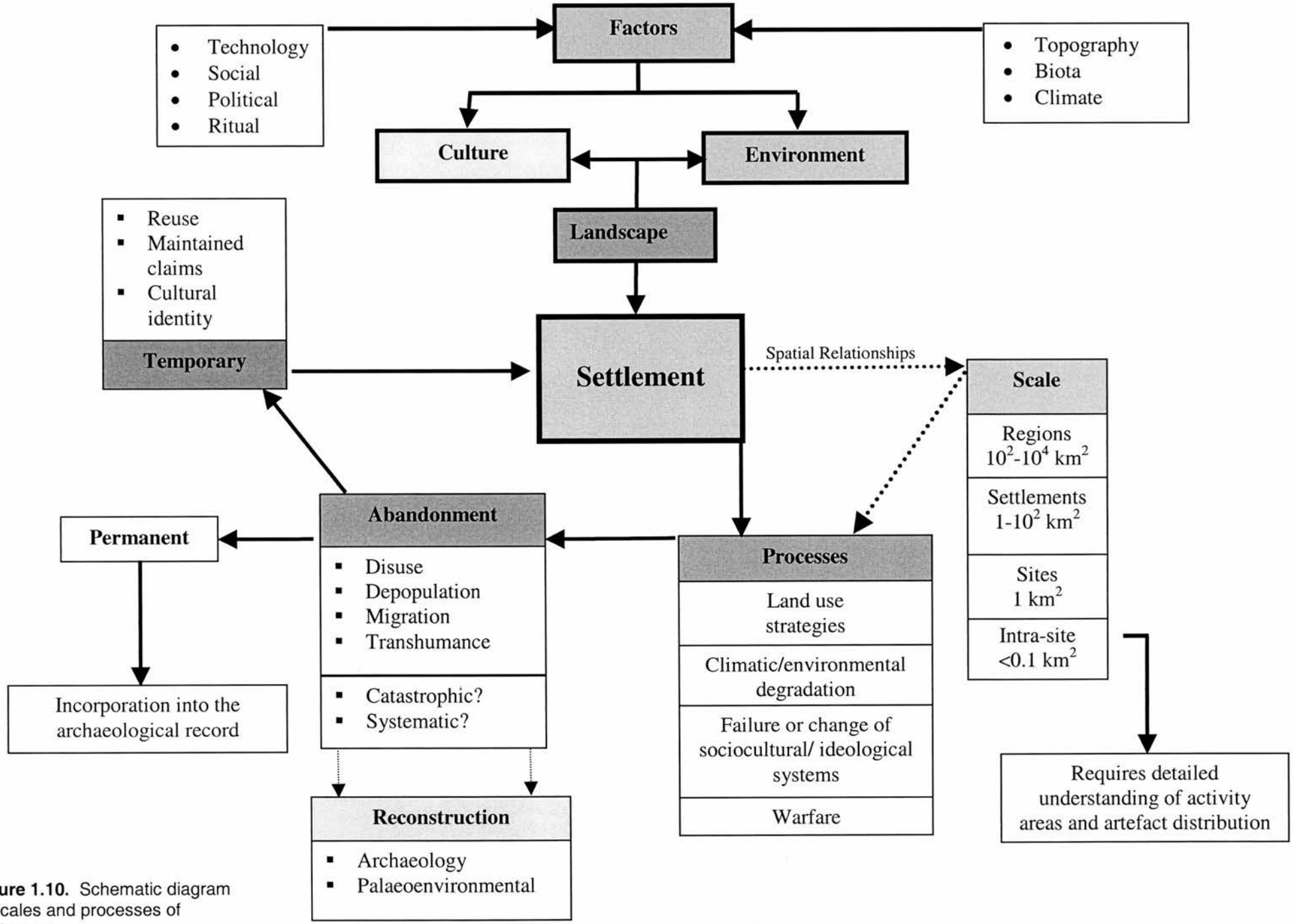


Figure 1.10. Schematic diagram of scales and processes of settlement.

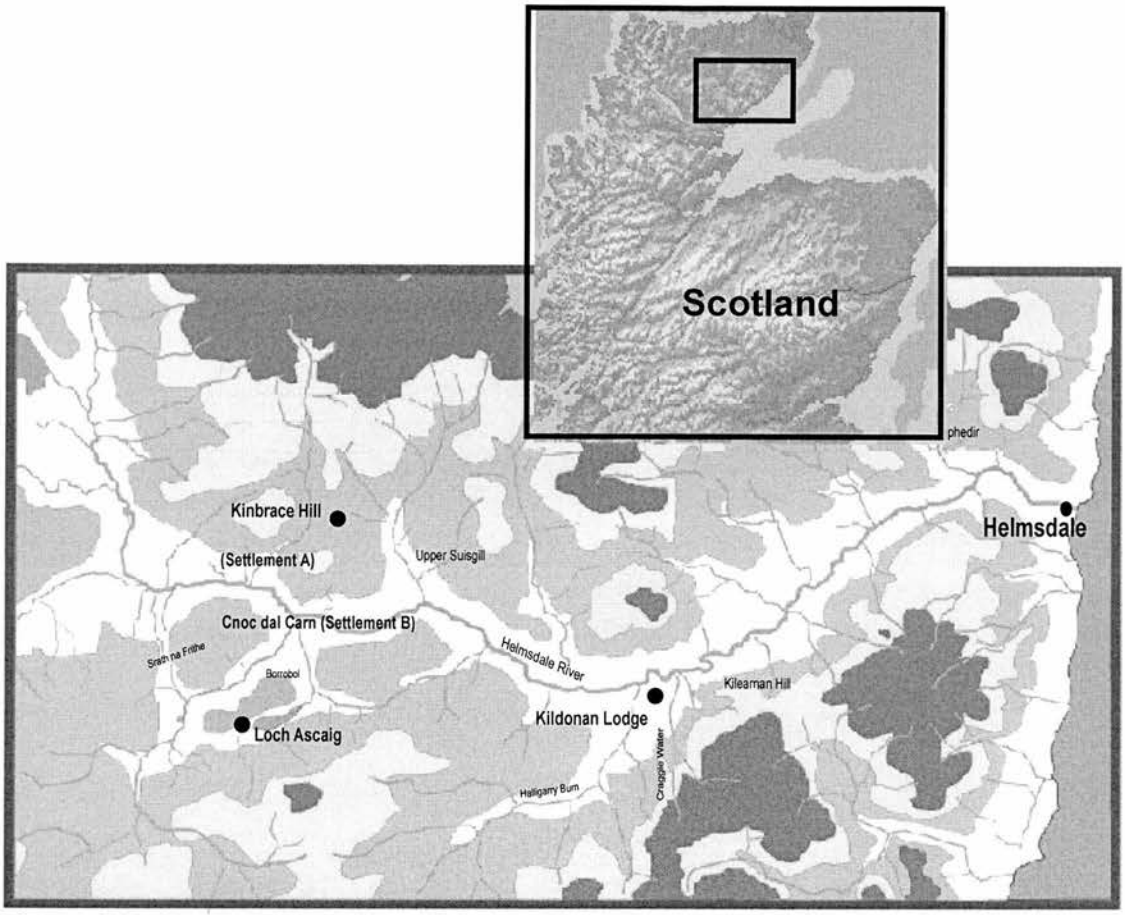


Figure 1.11. Map showing the location of the Strath of Kildonan in northern Scotland and a detail of the area of investigation.

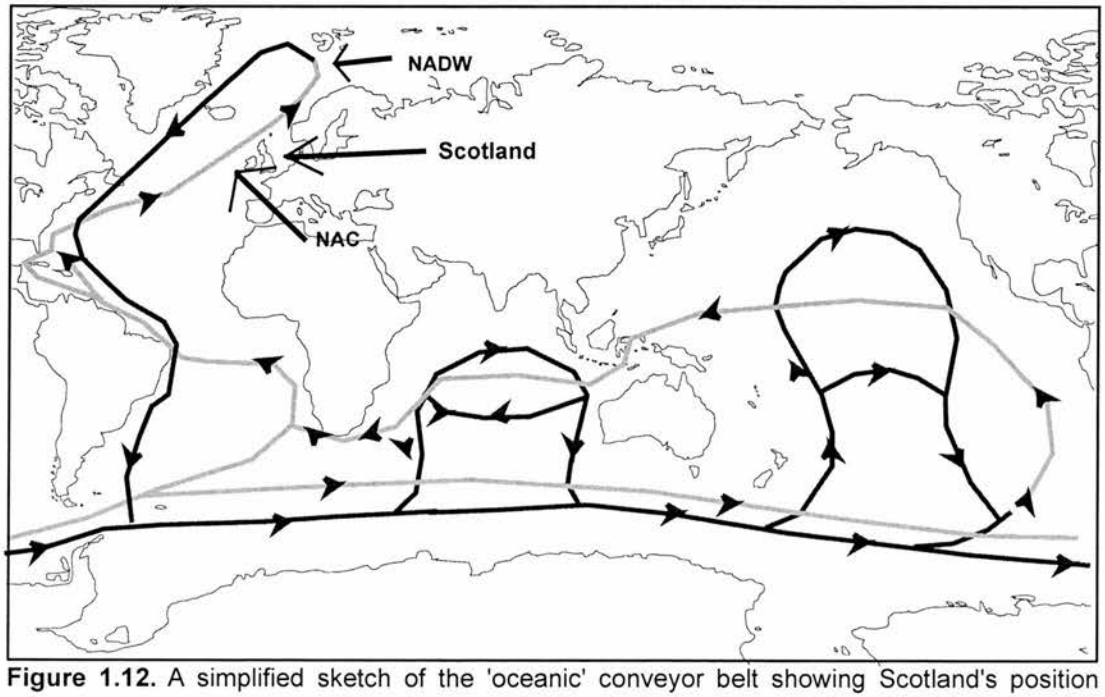


Figure 1.12. A simplified sketch of the 'oceanic' conveyor belt showing Scotland's position relative to the primary areas of deep water formation, the North Atlantic Deep Water (NADW) formation. The sketch also shows its location relative to the North Atlantic Current (NAC), the warm surface ocean current which gives the British Isles their characteristically mild weather.

Chapter 2

Late Holocene Climate Variability and Environmental Change in the North Atlantic

> "But a voyage to northern waters... has little to offer in the way of pleasure...beyond a bracing climate and spectacular scenery – icebergs, ice floes, ice mountains. Sunshine may well be less than that of an average English summer, for the North Atlantic on the whole is a region of cloud. [T]he crew... may be pent up in winter woollies... As for basking on deck, only the helmsman will spend any time there and he will be wrapped up in sweaters and oilskins."
>
> H.W. Tilman *Mischief in Greenland* 1964

Introduction

Understanding present day climates is crucial to understanding the significance of past climate changes. The climate and weather of the British Isles, and therefore Scotland, is intimately related to patterns of North Atlantic oceanic and atmospheric circulation. Chapter 2 will begin with a discussion of present day patterns of North Atlantic and British climate. This will be followed by a critical review of the evidence for climate change in the North Atlantic region during the Late Holocene and the potential forcing mechanisms involved in these changes. This discussion is important because very few archaeological approaches take into account the importance of the spatial and temporal scales of climate change when attempting to elucidate potential effects of these changes on human communities. Chapter 2 will conclude with a review of the evidence of palaeoclimatic variability and environmental change from northern Scotland with specific reference to the later prehistoric context of climate change.

The Climate of the British Isles

The surface weather of the British Isles is determined by the character of 'synoptic systems' or large scale weather systems which pass over the British Isles (Kelly *et al.*, 1997). Individual synoptic systems will interact with different characteristics of the land surface beneath, such as topography, aspect, and altitude, to produce the weather which is experienced on the ground. For example, synoptic systems at horizontal scales of 1,000-2,000km^2 can express significant local variability at scales

of 10-100km^2 across land surfaces (Davies *et al.*, 1997). Synoptic systems are directly influenced by interactions between the ocean and atmospheric systems.

The Ocean System of the North Atlantic

Surface ocean circulation in the North Atlantic is unusual because it is only one of two places on the globe where deep water formation takes place (Barry & Chorley, 1992). The relatively mild climate of the British Isles is often, although somewhat mistakenly, attributed to the Gulf Stream. Figure 2.1 illustrates the complex pattern of North Atlantic surface current circulation. As the warm Gulf Stream waters travel north, part of the stream is re-directed towards the east, becoming the Azores Current (AC), while the rest continues northwards as the North Atlantic Current (NAC). Just south of Iceland, the NAC is again divided. A new current of warm water, the Iceland Current (IC) travels into the Denmark Strait before breaking down further. The remaining component of the NAC continues its northward vector, travelling between Scotland and the Faeroe Islands.

These surface ocean currents are largely controlled by the wind, but the action of deep water formation also acts as a pull on the warmer, lower latitude surface waters, drawing them north to replace colder surface water as it sinks. As the warm waters of the NAC travel north, they release heat and moisture, gradually increasing in salinity and density, whilst declining in temperature. Once they reach the Nordic Sea, these waters sink, or 'downwell'. Below the thermocline, the circulation of deep ocean waters is driven by density gradients forming a current at depth. The bottom current flows southwards until it joins the east-west travelling circum-Antarctic bottom current and flows into the much less saline Indian and Pacific Oceans (Figure. 1.12).

The Atmospheric System of the North Atlantic

The heat transported to the North Atlantic region by the ocean system is an important control on the regional climate. However, the weather experienced by the British Isles is also intimately linked to the position and strength of various tropospheric air currents. Figure 2.2 illustrates the main components of Northern Hemisphere atmospheric circulation. A key feature is the Polar vortex, the mass of air which is centred on the North Pole. The irregular shape of this mass of is influenced by the complex arrangement of lnd and water in the Northern Hemisphere (Barry & Chorley,

1992). Comparison with the southern polar vortex reveals a more uniform shape, again, largely contoured to the shape of the Antarctic land mass. The prominent ridges and troughs apparent in the air mass, are called Rossby Waves, and make up the upper 'Westerlies'. The location of the prominent trough, the key area of jet stream flow, over Europe is more variable than similar features over North America and East Asia; it is sensitive to changes in overall circulation and observations have shown that it has altered its path by as much 20° of latitude during the past two centuries (Barrow & Hulme, 1997). The Sub-Tropical Jet, at 30° latitude, and the Polar Jet, at 60° latitude, are fast moving, highly concentrated zones of air in the Westerlies. The position of these zones is variable on a seasonal basis, but is also variable on longer timescales. Their relative positions closely dictate the pattern of storm-tracks across the North Atlantic.

Synoptic systems, or large scale weather patterns are influenced by changing meridonal temperature and pressure gradients in the atmosphere. These in turn are affected by seasonal inequalities in solar radiation between high and low latitudes and the angular momentum of the earth. For example, when the meridonal temperature gradient is at its greatest in winter, this acts to intensify the air flow of the jet streams (Barry & Chorley, 1992). The behaviour of the jet stream is also linked to changes in pressure associated with the Sub-Tropical High Pressure belt, located at 30° beneath the Sub-Tropical Jet. The equator-ward shift of this belt of high pressure anti-cyclones during winter results in the southward expansion of the Polar vortex. The strength and location of Hadley Cells is also a significant controlling factors in the position and relative intensity of the Westerlies. The Polar Front is where the colder Arctic air masses meet the warmer Sub-Tropical air masses; it is this thermal gradient which produces the mid-latitude Polar Jet Stream. The area between 50° and 55° is the main path of the high and low pressure synoptic systems (Figure 2.2).

The North Atlantic Oscillation

North Atlantic climate variability on a number of time-scales is greatly influenced by a persistent oscillation in mean sea level pressure (SLP) between the Icelandic Low (IL) and the Azores High (AH), called the North Atlantic Oscillation (NAO). The climatic effect of this pressure anomaly is most apparent in winter (Hurrell & van Loon, 1997 Hurrell *et al.*, 2002). The strength of the NAO is expressed as an index

which measures the SLP gradient between the IL and AH . High index NAO behaviour is associated with a deepening of the IL, and thus a steepening of the pressure gradient. Positive NAO behaviour results in stronger westerly air flow across mid-latitude NW Europe which transports warmer, moister air over the region (van Loon & Rodgers, 1978). In general, while winter storminess increases, temperatures are warmer than usual over NW Europe. Negative phases NAO generally result in more severe weather conditions, with a strengthening of easterly air flow as the Siberian High pressure systems expands westward, bringing drier, but much colder air to NW Europe.

In the period prior to the 1920s, low index NAO conditions were predominant. Iceland and Greenland experienced colder than average winters, as northeasterly air flow dominated (Kirkbride, 2001). Glaciers in Iceland were at their greatest extent in the late 19th and early 20th centuries than anytime since the LIA, or after the 1930s (Bradwell, 2001; 2002). Since the 1970s, the NAO, and another Northern Hemispheric oscillatory phenomenon, the Pacific-North America Oscillation (PNA), have largely been in a positive, resulting in warmer air temperatures in Europe, but cooler SSTs (Rind, 2002). The persistence of one mode for an extended period of time might be classified as 'climate change' (Rind, 2002). However, even when in a mostly positive or negative mode for extended periods, as during the past 150 years the NAO still exhibits a high degree of inter-annual variability (Hurrell *et al.*, 2002).

Decadal variability in both SSTs and NAO behaviour indicates a strong link between the two (Deser and Blackmon, 1993) although it is unclear whether these represent ocean responses to decadal atmospheric variability or ocean forcing of atmospheric systems on the same scale (Hurrel *et al.*, 2002). As an example, the 'Great Salinity Anomaly' of the 1950s and 1960s is associated with the development of a high pressure anomaly over Greenland, leading to extremely negative NAO conditions. This resulted in the increase southward flow of colder, less saline waters which formed a distinct subsurface layer that circulated around the North Atlantic for two decades.

The long term behaviour of the NAO and thus its influence on North Atlantic climate is only just beginning to be understood. Hurrell's (1995) review of meteorological

data from the last 150 years shows convincing evidence of the influence of the NAO on interdecadal climate variability, which he suggests may also be related to long term decadal variability reflected in the Greenland ice cores. Currently, proxy reconstructions of the NAO index only extend back 350 years using data from the Greenland ice cores (Barlow *et al.*, 1997). Keigwin (1996) reconstructed high resolution records of SSTs in the northern Sargasso Sea and discovered rapid, high magnitude centennial-scale shifts in SSTs during the past *ca.* 2,000 years. Periods of sea surface cooling were interpreted as signalling the onset of Little Ice Age conditions. It was subsequently suggested that this might be consistent with low NAO index conditions, but similar high resolution North Atlantic records are needed for comparison (Cronin, 1999).

Implications for Weather 'At the Ground' in the British Isles and Scotland

Although the regional characteristics of circulation patterns discussed above are an important control on the climate of the British Isles, the persistence of anomalous patterns over the course of weeks or months are also an important aspect of the British climate (Barry & Chorley, 1992). For example, a strong pattern of blocking over northern Scandinavia in 1947 pushed polar depressions further south than usual, resulting in higher precipitation over the British Isles from the moisture bearing depressions. In comparison, during a low NAO index winter in 1963, blocking occurred in the eastern North Atlantic. The resulting increase in the easterly flow of air caused a colder, but much drier winter (Davies *et al.*, 1997).

Britain experiences a significant north-south precipitation gradient. The droughts of 1975 and 1976 which affected the southern half of Britain, were not felt in northern or western Scotland . In 1984, between April and August, Scotland experienced 50% of its usual rainfall, whilst England recorded a period of unusually wet weather. Variation in precipitation and temperature is apparent on even smaller scales within Scotland. Figures 2.3and 2.4 highlight the differences between the more 'continental' climate of the east coast of Scotland, contrasting with more 'oceanic' west coast. Total annual precipitation for NW Scotland is similar to the English Lake District and western Norway because all of these areas tend to fall directly beneath the paths of North Atlantic depressions. However, Aberdeenshire, experiences a much lower total

annual precipitation, more closely related to that of southeast England (Barry & Chorley, 1992).

Almost endless examples of the various spatial and temporal dimensions of British and Scottish weather could be discussed. The key issue is that variability at all scales is the norm in British climate. The Later Bronze Age catastrophe requires that the expression of climate, weather and perceptions of these by human populations are uniform at all spatial and temporal scales. The above discussion does not preclude the possibility of a transition in climate state which could affect a large geographical area, but it does suggest that it might be expressed in different ways at a number of increasingly small spatial scales.

North Atlantic Late Holocene Climate Variability

The twentieth century represented a sea change in the perspective of global climate change, one that continues to be built upon as we enter the twenty-first century. The solar forcing of climate conditions on Milankovitch time-scales (23,000, 41,000 and 100,000 years) has been relatively well understood for sometime, dubbed " the pacemaker of the ice ages" (Hayes *et al.*, 1976). However, palaeoclimatology has also made crucial discoveries concerning the variability of the climate system on smaller time-scales, those more relevant to human experience. Much of the evidence concerning shorter term, sometimes abrupt, millennial-, centennial- and, to some extent, decadal-scale oscillations or transitions in the climate system comes from research into conditions governing the last glaciation and its termination (*cf.* Bond & Lotti, 1995; Bond *et al.*, 1997; Dansgaard & Oeschger, 1989; Heinrich, 1988; see also Broecker, 2000; Cronin, 1999; for reviews). To this can be added the increasing evidence for decadal and interannual Holocene variability extracted from ice cores (*eg.*, Meese *et al.*, 1994), tree rings (*eg.*, Stuiver & Brauzinas, 1987, 1993) and for later periods, instrumental records.

An intriguing aspect of reviewing the literature of Holocene climate change is the short shrift given to the period between *ca.* 4,000 cal BP and the Medieval Warm Period/Little Ice Age (*ca.* 400 cal BP). In journal publications, short articles and text books, only the briefest of sketches are dedicated to the climate of the mid- and later Holocene. These are usually book-ended by more exhaustive accounts of glacial

terminations and the climate of the past 500 years. Holocene climate variability, in contrast to Glacial/Inter-Glacial cycles, is characterised by a low 'signal to noise' ratio, where, for example, variations in temperature can be as little as 0.2-0.5°C (Overpeck, 1995; Rind, 1996). This feature contributed, in part, to the earlier notions of a stable Holocene climate, and continues to make the detection of significant changes difficult. Cronin (1999) has suggested that research into Holocene decadal- to centennial-scale climate variability is a 'fledgling field': the nature of climatic 'teleconnections' is still debated, as are potential climate forcing mechanisms, while in some areas, the North Atlantic in particular, higher resolution marine records are as yet unavailable for comparison with other data sets.

The Evidence: Palaeoenvironmental Data and Climate Reconstructions

Proxy climate data are derived from a number of sources *eg.*, oxygen isotopes, carbon isotopes, other cosmogenic isotopes, 'ice-rafted debris', foraminifera, peat sediments, tree rings and so on depending on the scale and area of the climate system on which research is focussed. The following discussion will focus on several of the most important sources of North Atlantic proxy climate data, marine and ice cores, tree rings and peat bogs, that have been used to reconstruct the climate of the past *ca.* 4,000 years.

Marine and Ice Cores

As mentioned above, North Atlantic marine records have only recently begun to contribute to knowledge about Late Holocene climate change in any detail. One of the potentially ground breaking discoveries of the last few decades is the recognition of the so-called 'Bond cycle' in North Atlantic marine sediments (Bond *et al.*, 1997, 2001). This 1,500 year periodicity in ice rafted debris events (IRDs) appears to be a pervasive and integral part of the North Atlantic climate system (Bond *et al*, 1997). The cycle is apparent over the past 150,000 years and persists through glacial/inter-glacial cycles; IRD events in the Late Holocene were identified at 4,200; 2,800 and 1,400 cal BP (Bond *et al.*, 1997, 2001). The IRD events represent periods of re-distribution of North Atlantic sea-ice and reflect cooler climate conditions in the North Atlantic region. Drifting sea-ice from Arctic regions and cooler surface waters from the Nordic and Labrador Seas advects further south and east than usual,

penetrating the warmer waters of the North Atlantic Current. The ice melts, depositing lithic grains on the sea bed, allowing the origins of the debris, and thus the ice, to be traced.

The case for IRD events representing a regional pattern of cooling is supported by other proxies in other Atlantic marine records. $\delta^{18}O$ records from the northern Sargasso Sea reflect cooler sea surface temperatures (SSTs) *ca.* 4,000-3,500; 1,700-1,500 and 300-1100 cal BP (Keigwin, 1996). Marine cores from the Rockall Plateau record minima in salinity and density indicating SSTs in that area were also reduced by 1°C *ca.* 3,800-3,300 and again *ca.* 3,000-2,500 cal BP. O'Brien *et al.* (1995) identified a 2,600 year cycle of cooling reflected in haline and dust concentrations in the GISP2 ice core. The increased concentrations of salt and dust result from stormier conditions, perhaps resulting in intensified polar circulation. Late Holocene events occur at 3,100-2,400 and at 600 cal BP. The most pronounced change was between 3,100 and 2,400 cal BP and they suggested it marked the onset of the current state of 'Neo-glaciation'.

Tree Rings

Tree ring records covering the entire Holocene have been available for sometime from North America (*cf.* Fritts, 1976). The record of growth from the early Bristle Cone pine series suggested a 1°C decline in temperature after *ca.* 2,500 BC. Lamb (1978) extrapolated this information to posit a 2°C drop for northwestern Europe, although reviewing the original text, it is unclear how Lamb was able to arrive at the figure. Since then, long tree ring chronologies have become available both from high latitude areas of the Northern Hemisphere such as Fennoscandia (*cf.* Briffa, 1994; Briffa *et al.*, 1992; Helama *et al.*, 2002) as well as mid-latitude temperate Europe, including more recently, Ireland (Baillie, 1995).

Northern Swedish records of summer temperature recorded in pine trees indicate what appear to be periods of significantly cooler temperatures *ca.* 4,200-4,000 BC; 3,200-3,000 BC; 2,200-1,900 BC; 1,700-1,500 BC; 1,200-900 BC and after 500 BC (Briffa, 1994). In the Irish oak chronology, it is suggested that the periods 4450-3900 BC; 3450-3100 BC; 2200-1900 BC and 1150-750 BC represent periods of cooler/wetter climate conditions (Baillie, 1995). More recently, a reconstruction of July

temperatures from pines in Finnish Lapland shows some off-set from these data, with cooler conditions occurring around 2,500-2,401 BC; 1,500-1,401 BC; 600-501 BC; 300-201 BC and AD 1501-1600 (Helama *et al.*, 2002). The periods 2,500-2,401 BC and 1,500-1,401 BC represent some of the coldest recorded, and the authors draw attention to the coincidence of the 2,500-2,401 BC cold 'event' and the 4,200 cal BP IRD event identified by Bond *et al.* (1997).

A more unusual use of the dendrochronological record comes from Germany. Here, radiocarbon dated remains of oaks in a floodplain environment were used as a proxy index of flood conditions (Spürk *et al.*, 2002). Using additional data from pollen analyses, it is argued that periods of low tree deposition marked episodes of human clearance and settlement. The renewed deposition of trees occurred as the abandonment of settlements allowed seedling establishment in the open woodland. It was inferred that the abandonment was caused by the onset of wetter, cooler conditions after 3870 BC, 2580 BC, 2100 BC, 1540 BC and 900 BC. Interpretation of the latter part of the record, it seems, is complicated by human activity in the form of more extensive and persistent clearance. It is further suggested that NAO or NAO-like behaviour is responsible for the periods of decreased tree deposition; *ie.*, positive NAO conditions would have caused drier conditions, conducive to settlement and agriculture. Transition to negative NAO conditions resulting in a wetter, although warmer, regime would have caused abandonment of the area.

Stuiver and Brauzinas (1987) reconstructed humidity and temperature changes during the last 2000 years from North American pine trees. This is significant in terms of the North Atlantic region, because the results of this work and a subsequent investigation (Stuiver & Brauzinas, 1993) indicate good agreement, firstly between the $^{13}C/^{12}C$ ratios and Greenland ice-core acidity data and, secondly between the GISP2 records of ^{14}C and $\delta^{18}O$. From their later results, several conclusions were made:

- Inter-annual (2-6 year) variability in ^{14}C production is related to ENSO and perturbations in the ocean system. This could help provide the basis for better understanding of global climate 'teleconnections' between, *eg.* ENSO and NAO.

Aaby (1976)	Draved Mose, Denmark	*ca.* 450	*ca.* 660 *ca.* 800		*ca.* 1500	*ca.* 1700		*ca.* 2250	*ca.* 3000	*ca.* 3400	*ca.* 4000. 4300. 4600
Anderson (1998) *	Northern Scotland		*ca.* 940-800							*ca.* 3340-3270	*ca.* 4020-3630
Barber (1981, 1984)	Bolton Fell Moss, N. England	*ca.* 210 *ca.* 500		*ca.* 1100 *ca.* 1170	*ca.* 1300			*ca.* 2270	*ca.* 2900	*ca.* 3600	*ca.* 3600
Blackford & Chambers (1991)	Brecon Beacons Wood Moss Harold's Bog Migneint Letterfrack	*ca.* 460		*ca.* 1150	*ca.* 1310 *ca.* 1330 *ca.* 1313			*ca.* 1910			
Chambers et al (1997)	Talla Moss, S. Scotland	*ca.* 540		*ca.* 1100		*ca.* 1700	*ca.* 1910	*ca.* 2270	*ca.* 2600	*ca.* 3460	
DuPont (1986)	Bourtangersveen, Netherlands						*ca.* 1950			*ca.* 3360 & 3650	*ca.* 3300 & 3650
Charman (1990)	Cross Lochs, N. Scotland								*ca.* 2890-2750		
Haslam (1987)	NW Europe			*ca.* 1150		*ca.* 1850			*ca.* 2550-3050		
Hughes (1987)	Abbeyknockmoy, Ireland									*ca.* 3500	*ca.* 3500
Hughes et al. (2001)	Walton Moss, N. England					*ca.* 1750		*ca.* 2320-2040	*ca.* 3170-2860	*ca.* 3500	*ca.* 3500 & 4410-3990
Korhola (1995)	Isuoso Tremanskarr Kantosuo										*ca.* 4300
Nilssen & Vorren (1991)	20 bogs from N. and C. Norway	*ca.* 420	*ca.* 720 *ca.* 850	*ca.* 1140	*ca.* 1400	*ca.* 1680	*ca.* 1930	*ca.* 2230 *ca.* 2450	*ca.* 2800 & 3120	*ca.* 3370	*ca.* 3370 & 3780
Tipping (1995)	Kirkpatrick Fleming	*ca.* 400			*ca.* 1200			*ca.* 2050			*ca.* 4000
Van Geel (1978) & et al. (1996)	Engbertsdijksveen, Netherlands								Ca. 2850, 3020 & 2750-2450	*ca.* 3750	*ca.* 3750
Wimble, 1986	Foulshaw Moss Heslington Moss White Moss N. White Moss S.		 *ca.* 600 *ca.* 800	 *ca.* 1050	*ca.* 1350 *ca.* 1500	 *ca.* 1700		 *ca.* 2250 *ca.* 2250	Ca. 2900 Ca. 2900 Ca. 2900	*ca.* 3400 *ca.* 3400 *ca.* 3500	*ca.* 4300 *ca.* 3800

Table 2.2. Summary and comparison of climate 'deteriorations' inferred from palaeohydrological shifts in mire surface wetness. All ages are calibrated calendar years BP. Adapted from Hughes *et al.*, 2001 except *.

Location	Periodicity	Climate cycle	Solar Minima	Publication
Draved Moss, Denmark	260-year	???	—	Aaby, 1976
NW Scotland	80-125-year	Gleissberg	Spörer & Maunder minima	Baker *et al*, 1999
Talla Moss, S. Scotland	208-year	Suess	Spörer minimum	Chambers *et al.*, 1997
Bolton Fell Moss, N. England	800-year	IRD		Barber *et al.*, 1994
Ireland, N. England	210-year	Suess	Spörer minimum	Blackford & Chambers, 1995

Table 2.3 Inferred periodicities in Holocene climate from peat bogs. Possible solar links suggested in the original publications are also give

Minima(MI)	Age
Wolf	AD 1281-1342
Spörer	AD 1450-1534
Maunder	AD 1645-1715
Dalton	AD 1783-1825

Table 2.4 Historically documented solar sunspot minima.

Sunspot Cycle	Periodicity	Description
Schwabe	10-11-year	Sunspot cycle
Hale	22-year	"Double sunspot" (solar-magnetic cycle)
Gleissberg	80-90-year	Sunspot/envelope modulation
Suess	180-206-year	

Table 2.5. Sunspot cycles. Similar periodicites have been revealed in records Of atmospheric 14C and in mire surface wetness.

- Decadal (10-11 year) cycles are related to solar modulation of cosmic ray flux which influences ^{14}C production in the atmosphere or instability in the North Atlantic thermohaline circulation, which affects ^{14}C storage in the oceans.
- A 206-year periodicity is linked to solar modulation of cosmic ray flux, possibly modified by a climate/ocean response, *ie.*, minor Maunder minimum-like changes in solar irradiance are amplified by changes in North Atlantic thermohaline circulation.
- A 512-year periodicity which is strongest in the early Holocene is linked more directly to thermohaline instability in the North Atlantic.

Stuiver and Brauzinas (1993) concluded that there was no convincing evidence that changes in the rate of ^{14}C production are linked causally to climate change.However, they argue that the results indicate a strong relationship between solar forcing mechanisms at sub-Milankovitch time-scales, indicated by alterations in the production of ^{14}C, and changes in the Greenland climate (Grootes and Stuiver, 1997). Identifying periodicities such as these in the palaeoenvironmental record (Table 2.1) is one step towards constructing a more secure foundation for interpreting relationships, feedbacks, links and the mechanics of climate and climate change.

Proxy	**Cycle**	**Publication**
Tree rings	143, 218, 420-year	Stuiver & Brauzinas, 1989
Holocene glacier fluctuations	88, 440, 1640-year	Bray, 1970
Camp Century ice core isotopes	78, 181, 400 , 240- year	Johnsen *et al.*, 1970
IRD events	1,500-year	Bond *et al.*, 1997
GISP2 haline and dust concentrations	2,600-year	O'Brien *et al.*, 1995

Table 2.1. Identifying and matching periodicities in palaeoclimatic record is one way to elucidate links and mechanisms which mitigate some of the problems associated with correlating radiocarbon dated horizons.

Peat bogs

Chapter 1 introduced the long term role that peat bogs have played in providing information about past climate conditions. The value of this early work was limited by a misapprehension about how peat bogs grow, something only rectified with Barber's (1981) study of peat bog growth and climate change at Bolton Fell Moss in northern England. It had for some time been believed that the hummock and hollow topography of mire surfaces succeeded each in other in a pattern of cyclical succession, represented by bands of lighter and darker sediments in peat (Barber, 1981). However, Barber showed that changes in peat stratigraphy are not related to hummock-hollow patterns, rather that climate change is the controlling factor in peat bog growth. Crucially, it was demonstrated that rather than recording discrete shifts in climate, the peat bog archive can yield continuous detailed proxy records of climate variability. Initially, palaeoclimate reconstructions were confined to ombrotrophic, or 'rain-fed' bogs. These types of mire receive their moisture only from the atmosphere and as such are considered to be sensitive to changes in precipitation. More recent work has shown that blanket mires, although lacking the visible changes in stratigraphy characteristic of raised mires, are also capable of producing high-quality, continuous records of proxy climate change (Blackford, 1990; Blackford & Chambers, 1991, 1995; Chambers *et al.*, 1997).

Table 2.2 is a summary of the age ranges of shifts to wetter conditions recorded in NW European peat bogs, although the emphasis is on data collected in the British Isles. It has been noted that certain wet shifts are more broadly represented than others, *eg.* the shift between *ca.* 4,410-3,990 cal BP and a second one *ca.* 2,900-2,700cal BP (Hughes *et al.*, 2001). The so-called 'Dark Age deterioration *ca.* 1,500-1,400 cal BP (Blackford & Chambers, 1991) is also well represented. Shifts to wetter conditions frequently correspond with the beginning of the Little Ice Age (LIA) which is usually associated with the Spörer sunspot minimum. Table 2.3 illustrates the wet shifts associated with other historical observations of sunspot minima (Table 2.4), most of which occur during the LIA and each average around 80 years in length. The Wolff minimum is slightly earlier and occurs towards the end of the 'Medieval Warm Period' (MWP).

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In an effort to better link the terrestrial records of proxy climate change to the overall picture of regional climate change, time series analysis has been increasingly applied to humification records. Aaby (1976) was the first to do this, although the 260-year periodicity in mire surface wetness identified at Draved Mose, Denmark has not been replicated. This and the results of subsequent application analyses of humification data are summarised in Table 2.3. There is strikingly good agreement with cycles of solar variability (Table 2.5), as well as the coincidence of shifts to wetter conditions with historical observations of solar minima (Table 2.4). The obvious outlier is the 800-year periodicity from Bolton Fell, Moss (Barber *et al.*, 1994). They suggest that this is 'ocean-driven', with an oblique reference to the Bond cycle (1470±500 years). They do not explain exactly how the shifts in mire surface wetness might be linked to the IRD events.

The current inability to quantify terrestrial data sets of palaeohydrogical change from peat bogs is a slight drawback. However, records can still impart to some extent a qualitative perspective of the magnitude and the persistence of palaeohydrological shifts. Future development of techniques using testate amoebae to reconstruct water table height will make a significant contribution towards quantifying humification data (*eg.*, Charman *et al.*, 1999; Hendon *et al.*, 2001). Other peat bog work highlighted above has shown the scope for statistically reconstructing frequencies and periodicities of mire surface wetness (*eg*, Blackford & Chambers, 1995).

Evidence for Climatic Amelioration

The focus of investigations into Holocene human-environment interactions has been characterised strongly by elements of doom-mongering. Reading the literature concerning NW Europe, and excepting the much debated Medieval Warm Period, it might be easy to imagine that humans for the last 4,000 years have done nothing but suffer the privations of deteriorating climate. For the moment, the obvious pitfalls behind subjective categorizations of climate as 'ameliorated' or 'deteriorated' will be disregarded. The following is a brief summary of the evidence indicating periods of warmer, drier climatic conditions during the Late Holocene.

Helama *et al* (2002) identified several period of relative Holocene warmth in the Fennoscandian tree-ring record including 1190-1161 BC, 300-201 BC, AD 560-531 and AD 1541-1570. Reconstructions of summer temperature from Swedish tree ring records reflect warmer conditions generally between 4000-3300 BC, and other notable, but shorter warm periods at 2900, 1300 and 750 BC (Briffa, 1994). Between 900 and 1100 cal BP, SSTs in the Sargasso Sea underwent significant warming (Keigwin, 1996). Domack & Mayewski (1999) identified 6 'warm' events which are inferred to be decreased winter circulation of maritime air masses lasting approximately 200 years. These were at *ca.* 700 BC, AD 250, AD 400, AD 800, AD 1250 and AD 1600. Further examination of the GISP2 chlorine record indicates two other possible warm periods at 1400 BC and 2400 BC. The end of the 1400 BC warm period is marked by a notable upward excursion of chlorine values, the 2,800 cal BP cold event cited by O'Brien *et al.* (1995).

The Roman Optimum

It has long been suspected that the expansion and success of the Roman occupation of Britain was assisted by a period of climatic mildness between 200 BC and AD 400. Lamb (1981) dubbed this the 'Roman Optimum'. Palaeohydrological reconstructions from Bolton Fell Moss, in northern England indicate a shift to drier conditions *ca.* AD 200, which persisted until the 7th century AD (Barber *et al*, 1997). Tipping (1995a) also identified a period of warmer, drier conditions which persisted until *ca.* AD 650 at Kirkpatrick Fleming in SW Scotland. Conversely, at nearby Talla Moss a shift to wetter conditions was recorded in the early centuries AD, marking the end of a period of warmer drier conditions (Chambers *et al.*, 1997).

The Medieval Warm Period

From *ca.* AD 700-1300 occurred a period of apparent climatic amelioration, often referred to as the 'Medieval Warm Period' (MWP) (Lamb, 1977, 1982; Grove, 1979). A more circumscribed period between AD 1100-1250 is defined as the Medieval Warm Epoch, which coincides with the Mediaeval solar maximum (Jirikowic & Damon, 1994 *in* Cronin, 1999). The tendency has been to cast the MWP and the LIA as contrasting periods of warmth and coldness, however more recent investigations of Lamb's original records and proxy climate data indicate that the reality of the MWP (and, consequently the LIA) is more complex than previously imagined (Ogilvie &

Farmer, 1997). The temporal and spatial expression of warmth appears, however, to have been quite variable across Europe and the North Atlantic (Overpeck, 1995). For example, between AD 1260 and 1360, historic records indicate that England experienced unusually cold winters (Ogilvie & Farmer, 1997), which overlap with the observed Wolff solar minimum (Table 2.4).

Mechanisms of Holocene Climate Variability

Identifying the occurrence of oscillations or transitions in different parts of the climate system solves only one part of the puzzle. Better understanding of the mechanisms which force climate change and link different parts of the system is crucial for understanding the human scales and significance of climatic change. Overpeck (1995) presents five mechanisms considered to be the most probable causes of short-term climate change. Of these only the four most relevant to this research, solar variability, ocean circulation, volcanism and atmospheric processes will be discussed. Overpeck considered these the most likely cause of centennial- and decadal-scale change. In the few years since this paper was published, millennial scale changes have been increasingly, and controversially, viewed as a product of solar forcing. Therefore, millennial scale changes, in particular, the 'Bond cycle' are included in the following discussion of climate forcing mechanisms during the Holocene.

Solar variability and Atmospheric Circulation

The direct cause of the IRD events is fairly straightforward; identifying the mechanism behind the events has proved controversial. Initially, it was suggested that the IRD events may have been caused by oscillations internal to the atmosphere (Bond *et al.*, 1997). An increased northerly and/or northeasterly flow of air would have cause the apparent shift in ocean surface hydrography, pushing cooler ice-bearing waters further south. More recently, Bond *et al.* (2001) have rejected suggestions that the IRD events are the product of internal re-organisations of the ocean system (*cf.* Broecker, 2000; Broecker *et al.*, 1999; see below) or the atmosphere (Cane *et al.*, 1999). Based on comparisons with cosmogenic ^{10}Be curves from GISP2 and production rates of atmospheric ^{14}C reconstructed from tree rings (Stuiver *et al.*, 1998), Bond *et al.* (2001) argue that fluctuations in solar irradiance are the forcing factor behind the IRD events.

Stuiver and Brauzinas (1993) suggest two primary mechanisms by which the small changes in solar irradiance might be translated into regional or even global scale climate re-organisations:

- Declining solar radiation causes a corresponding decrease in tropospheric temperatures and, in areas where deep water formation is important (*ie.*, the North Atlantic), an increase in precipitation. The long term effect of increased freshwater input into the North Atlantic waters would decrease the salinity (thus, density) of surface waters. The 'lighter' waters sink more slowly and deep water formation slows. Slower deep water formation means that warmer surface water of the NAC will not been drawn northward as much, reducing the transport of heat to the region, thereby reinforcing and amplifying the small magnitude changes affecting the troposphere.
- The amount of ultra-violet (UV) radiation in the stratosphere also declines as total solar irradiance declines, a change of much greater magnitude than the temperature decrease experienced by the troposphere. The decrease in UV radiation causes a surge in plankton growth in the world's oceans. The subsequent increase in dimethylsulphide (DMS), a by-product of plankton growth, could produce enough condensation nuclei to significantly enhance precipitation. Again, amplifying effects would be felt in areas where deep water formation is important.

Two additional mechanisms were proposed by van Geel *et al.* (1998) and van Geel & Renssen (1998):

- Decreases in stratospheric O_3 levels would cause cooling in the upper atmosphere and decreased intensity of stratospheric winds. This would result in the contraction of Hadley circulation and the equator-ward expansion of the jet stream. Strengthened Polar circulation would cause the southward displacement of the mid-latitude depression tracks (Figure 2.5)

- Decreased cosmic ray flux could contribute directly to increased cloud cover. The formation of low altitude cloud cover is believed to increase cooling because of higher albedo. High latitudes would be the most heavily impacted, since equatorial locations are protected by geomagnetic interference.

These last two publications also suggest as a third possible mechanism a direct impact on thermohaline circulation which is discussed in greater detail below.

The evidence from peat bogs, thus far, offers some support for the Sun's role in climate change (*eg.*, Stuiver & Brauzinas, 1993, 1997; Bond *et al.*, 2001; Magny, 1993; van Geel *et al.*,1998) by relating changes in solar variability to increases in precipitation and reductions in temperature across the North Atlantic region at various times. Importantly, like the results of Rind and Overpeck's (1993) modelling exercise, there is a regional heterogeneity in the humification data, as well. The spatial variation observed both in the timing of shifts and in periodicities may be a further indication of response to different mechanisms involved in re-organisations of the climate (Huntley, 1999), *eg.*, coastal sites might respond primarily to changes in SSTs/ocean circulation which perturb atmospheric processes; inland sites may respond primarily to atmospheric- orographic interactions.

The importance of solar variability as a forcing mechanism remains controversial, however, even at Milankovitch time-scales (Cronin, 1999; Rind *et al*, 1989; Rind, 2001). It is the fractional change in irradiance (0.09%) associated with, for example, high sunspot numbers that often provokes scepticism. Although workers have sought to identify mechanisms which could amplify these minute changes in solar radiation, actually proving the case that solar variability causes climate change is difficult (Cronin, 1999). The unsolved question remains: Is the Sun a controller of climate change, or is it only a prime mover of internal climate system feedbacks which are stronger than the Sun's influence itself (Rind, 2001)?

Thermohaline and Atmospheric Circulation

Broecker (2001) and Broecker *et al.* (1999) argue that the causal factors behind the IRD events are changes in ocean circulation, *contra* Bond *et al.* (2001). It is

suggested that the 1,500 year cycle is paced by a 750 year cycle in deep ocean re-organisation (Broecker, 2000). Rather than stronger atmospheric circulation pushing sea-ice further south, periodic internal adjustments in the pattern of ocean surface currents are responsible for advecting ice further south. Much like the enhanced precipitation models discussed above, the melting sea-ice acts to slow down the deep water formation, although the added influx of cooler water also results in a much more immediate decline in SSTs. The extent to which the ocean circulation conveyor belt is slowed down has a direct effect on the geographical imprint of climate changes. If salinity concentrations of the North Atlantic become too high, the conveyor would 'shut down' and leave a global imprint on climate, if the conveyor is merely slowed down, effects would be felt primarily in the North Atlantic (Stocker, 2000). Complete shut down is usually prevented by a 'salt oscillator' mechanism which transports excess salt to the Pacific and Indian Oceans. However, off-modes do happen and are represented by high magnitude climate 'jumps' like Dansgaard/Oeschger (D/O) events.

Bond cycles, on the other hand, may indicate patterns of reduced deep water formation. Like D/O events on a smaller scale, the southward expansion of sea-ice results in a steepening of meridional temperature gradients meaning colder winters and enhanced storminess (Broecker, 2000; Broecker *et al.*, 1999). The loading of the upper atmosphere with dust and sea salt with the stronger atmospheric circulation may be reflected in the signal in the GISP2 record (*cf.* O'Brien *et al.*, 1995). Increased dust loading in the atmosphere would provide a positive feedback mechanism for Northern Hemisphere cooling by increasing the albedo, and consequently further influence wind patterns and ocean surface circulation. Some support is lent to this theory by coupled ocean-atmosphere models which respond to melt-water influxes with a reduction or collapse of the thermohaline circulation (Stocker, 2001).

Volcanic Eruptions

The exact effect of volcanic eruptions on the climate, like solar variability, continues to be debated. Lamb (1970) presented a dust veil index (VEI), a measure of the amount of aerosols injected into the atmosphere by a given eruption and its potential to being about surface cooling. The screen of dust produced by the particulate matter would increase cloud cover through radiative cooling, as well as providing

hydroscopic nuclei and increasing precipitation. Lamb believed that there was a causal relationship between volcanic eruptions and increases in the extent of sea-ice around Iceland. The idea that volcanic eruptions were a major player in Northern Hemispheric climate change gained popularity with the discovery that acidity peaks in the Crete ice core from Greenland, representing a proxy of volcanic eruptions, appeared to correlate with lower atmospheric temperatures (Hammer *et al.*, 1980).

The VEI has largely been abandoned as it has become apparent that the variability in the nature of different eruptions and their location significantly influences their potential environmental and climatic impacts. Some argue that low latitude eruptions are the most likely to have significant impacts on global climate and the amount of sulphates and other aerosols injected into the atmosphere may also have more of an effect than the overall 'explosivity' of the eruption (Jakosky, 1986). Subsequent observations of historical and present day eruptions lend support to this argument, *eg.* Tambora, Mt. Pinatubo However, while global surface cooling caused by low-latitude eruptions may be very small, mostly fractions of a degree Celsius, local temperatures may decline up to 1.5°C (Dunbar, 2000). On a similar basis, more recent publications continue to argue that mid-latitude volcanic eruptions cause regional and possibly hemispheric perturbations in climate (Zielinski, 2000). Briffa (2000), like Baillie (1989, 1990) believes that narrow tree rings in high-latitude dendrochronological records *do* record volcanically induced climate cooling. All three authors believe these phenomena are detrimental to humans on scales ranging from decades to centuries.

In short, whilst some believe individual eruptions can have a significant impact on an inter-annual scale, overall, volcanic eruptions are not considered to be an important climate forcing factor over long periods of time or large geographic areas (Mass & Portman, 1992; Overpeck1995). Others still contend that eruptions can force large magnitude temperature reductions as frequently as once a century or possibly on longer millennial scales. As with teasing out the exact role of the Sun in climate variability, distinguishing a unique fingerprint of volcanic eruptions is likely to prove challenging. More recently, the climatic role of past Icelandic eruptions on climate has been discounted (Grattan & Gilbertson, 1994; Sadler & Grattan, 2000). Although, as discussed in Chapter 1, some continue to argue that the 'marginal' soils of upland

Britain are, and would have been in the past, vulnerable to acid rain caused by the injection of acid volatiles into the atmosphere by Icelandic volcanic eruptions.

A Scottish Connection: Climate and Environmental Change in a North Atlantic Context

With exception of Smith (1998), a majority of published palaeoecological reconstructions from northern Scotland do not offer much in the way of detailed analysis of human impact on the landscapes. All mainland northern Scottish sites referred to in the text are shown in Figure 2.6. In most cases, research was undertaken with the intention of reconstructing vegetation change in terms of climatic changes on larger spatial and over longer temporal scales (Tipping, 1994). The detection of human impacts has been often serendipitous rather than directed because of the large pollen recruitment areas of the lochs where these studies were often conducted (Tipping, 1994). This makes it difficult to formulate a precise picture of human-climate interaction across northern Scotland.

Only recently, with the excavations at Lairg in northern Scotland (McCullagh & Tipping, 1998) , have pollen analytical studies in the region been undertaken with the role of elucidating human impacts on the landscape. Proxy climate reconstructions are sparse in northern Scotland compared to the rest of the country. The primary source of Holocene palaeoclimate data comes from a set of detailed proxy reconstructions from three peat bogs in Wester Ross (Anderson, 1998.Less detailed reconstructions were undertaken during the Lairg excavations (Dixon, 1994)). A series of studies were also undertaken on the NW coast of Sutherland using parallel records from speleothems and peat bogs overlying the caves where the speleothems were taken (Baker *et al.*, 1995, 1999; Charman *et al.*, 1999). Recent palaeoclimate reconstructions from the NW coast have made tentative connections between inferred climate changes and the contraction of settlement in northern Scotland (Anderson *et al.*, 1998).

A recent review of the history of Scottish woodland illustrates that, prior to 4,000 cal BP, the woodland of the far north of Scotland reflected three broad patterns (Tipping, 1994): Caithness and the far NW of Sutherland appear to have been an open birch

and hazel woodland. Peglar (1979) suggested that the woodland around the Loch of Winless in NE Caithness had affinities with the birch/hazel scrub of the Northern Isles. The forests of Wester Ross and the rest of Sutherland, except for a narrow strip along the eastern coast, were comprised mainly of pine woods or mixed pine-birch woodlands. On the east coast of Sutherland, and south to Dornoch and Moray there were deciduous woodlands of mixed birch, hazel and oak. The dominant tree types in any given locale within these broad patterns would have, of course, depended on edaphic factors and other local conditions.

Anderson (1998; also Anderson *et al.*, 1998) recorded several Late Holocene shifts to wetter, cooler conditions in several peat bogs across Wester Ross in northern Scotland. (Figure 2.7). Wet shifts were recorded at ca. 3,900-3,500 cal BP. A humification record from a catchment in Achany Glen in eastern Sutherland, shows a shift to wetter conditions *ca.* 4,100 cal BP (2200 cal BC) (Dixon, 1994), and this is accompanied by a rise in lake level in the same catchment (Smith, 1998). These changes are consistent with other palaeoclimatic data reflecting lake level rises across Scotland between 4,000 and 3,000 ^{14}C BP (Yu & Harrison, 1995) and other data relating to the potential climatic causes of the decline of *Pinus sylvestris* in Scotland (Anderson *et al.*, 1998). On Ben Arkle in NW Sutherland, peat beneath a solifluction lobe was dated to 3,984±55 BP (4,420 cal BP), thought to be related to climatic deterioration (Mottershead, 1978).

The results of Bridge *et al.* (1990) tentatively support Dubois and Ferguson's (1985) hypothesis of Late Holocene 'pluvial' episodes at 4,250-3,870 ^{14}C years BP and 3,300 ^{14}C years BP, with declines in radiocarbon-dated pine stumps at 3,800-3,500 ^{14}C years BP and after 3,250 ^{14}C years BP in the Cairngorm Mountains in the Scottish Highlands. It was suggested further sampling would need to be undertaken, although they conclude that the available evidence suggests the influence of long term precipitation trends on the distribution of the pine population in Scotland. Birks (1975) noted that most of the pine stumps recovered from peats in western Caithness and eastern Sutherland reflected poor growth, suggesting that pine was growing near its ecological threshold in these locations. Despite the slight temporal variation between 4,200 and 3,500 ^{14}C years BP in 'pine declines' across the far north of Scotland, it was suggested that the expansion and disappearance of pine from most of

northern Scotland was the result of changing circulation patterns, possibly related to the NAO or NAO-like behaviour (Gear & Huntley, 1991; Huntley *et al.*, 1998).

Drier conditions allowed *Pinus* to invade blanket peats in northern Scotland sometime prior to *ca.* 4,000 BP (Gear & Huntley, 1991; Huntley *et al.* 1998), however, the subsequent onset of cooler, wetter conditions resulted in conditions unfavourable to the growth of *Pinus* such as waterlogging, soil leaching, podsolisation and paludification (*eg.*, Bennett, 1984, 1986; Birks, 1975; Bridge *et al.*, 1990; Gear & Huntley, 1991). The potential causal role of volcanic eruptions has largely been rejected (Hall *et al.*, 1994). A recent investigation showed that in a number of profiles, the pine decline preceded the deposition of the Heka 4 tephra horizon (Daniell, 1997). The findings of Blackford *et al.* (1992) were further questioned on the grounds that *Pinus* may not have been growing locally at the time of the tephra deposition, and that the local decline may have occurred earlier, before the peat profile began accumulating (Tipping, 1994; Huntley *et al.*, 1998). Further work by Hall (2003) has shown that the deposition of the Lairg B tephra *ca.* 5,000-6,000 BP had no demonstrable effect on vegetation, and interpretation of the record is not complicated by the human impacts at this period.

At Loch Craggie (Pennington *et al.*, 1972), the slight evidence for arable and pastoral activity *ca.* 4,300 cal BP (*ca.* 2750 cal BC) appears unrelated to any major reductions in woodland cover. The decline at Loch Sionscaig (Pennington, *et al.*, 1972) coincided with a peak in charcoal, but no 'indicator species' (*cf.* Behre, 1981) were recorded. A profile from blanket peat near Loch Sionscaig (Pennington *et al.*, 1972), is the only definitive evidence on palynological grounds for early human impacts in NW Scotland, recording a substantial episode of clearance and pasture development *ca.* 3,400 cal BP (*ca.* 1500 cal BC). At Loch Maree (Birks, 1972) woodland disturbance appears to have been climatic in origin *ca.* 4,100 cal BP (*ca.* 2200 cal BC).

Profiles from the Aukhorn peat mounds, Keiss, Caithness recorded only indistinct human impacts prior to *ca.* 3,400 cal BP (*ca.* 1500 BC), after which to the present day, the profiles reflect the expansion of *Calluna* heath, blanket peat and grassland under a combination of agricultural and climatic influence (Robinson, 1987). At Loch

of Winless, Caithness wetter climatic conditions were inferred from vegetation changes after 4,500 ^{14}C years BP (Peglar, 1979). There is no reliable evidence of Late Neolithic to Early Bronze Age human activity beyond a few indicators for the development of pasture around 4,000 ^{14}C years BP. Despite the lack of evidence in pollen diagrams, the early presence of humans in this area cannot be discounted, given the extensive evidence of occupation, mostly in the form of chambered tombs. Charman (1994) suggests that the evidence for woodland decline between 5,500-4,250 ^{14}C years BP may overlap with the building of chambered tombs in the area around the Flow Country Caithness.

In south eastern Sutherland, more reliable and detailed evidence for early human impacts is available from an area of upland settlement in Achany Glen (Smith, 1998). Here cereal cultivation was identified as early as *ca.* 3700-2900 cal BC, while grazing was apparent from *ca.* 2500 and 2200 cal BC (Smith, 1998). Separating the significance of human impacts from the influence of the pine decline is difficult (Tipping & McCullagh, 1998), but it is possible that humans, as well as climatic factors, may have exerted some influence on the population of *Pinus sylvestris* in Achany Glen and after *ca.*1800 cal BC, the human impact on the landscape becomes much more apparent (Smith, 1998; Tipping & McCullagh, 1998). The pine decline at Cross Lochs was preceded by a substantial rise in microscopic charcoal, possibly related to nearby settlement, and may also indicate some human pressures on *Pinus* (Charman, 1994).

After *ca* 3,000 cal BP, identifying climatic impacts in the proxy records from peat bogs becomes complicated by human impacts, but correlation with other records may indicate the occurrence of regional scale shifts to cooler, wetter conditions. A shift to wetter conditions was recorded in only one of the three peat bogs studies Wester Ross between 2,800-2,540 cal BP (Anderson, 1998; Anderson *et al.*, 1998). In the Flow Country, a shift to wetter conditions was also recorded *ca.* 2,890-2,750 cal BP (Charman, 1990). In eastern Sutherland, a second increase in lake level was recorded substantially earlier in Achany Glen *ca.* 3,150 cal BP (1400-1200 cal BC) (Smith, 1998). Baker *et al.* (1995) tentatively invoked the Hekla 3 eruption as a causal factor of enhanced growth of a speleothem from the Uamh an Tartair cave system in NW Sutherland *ca.* 1135±130 BC which persisted for four years. It was suggested that the

growth reflected anomalous conditions, not predicted within the parameters of 'normal' climate variation, and vegetation removal by acid rain from the Hekla eruption resulted in increased groundwater levels.

The shift to wetter conditions identified in Wester Ross (Anderson, 1998) and Caithness (Charman, 1990) is consistent with other British and North Atlantic palaeoclimate records. It is one of the most widely recorded shifts to wetter conditions in European and British peats bogs (Table 2.1). In addition, it appears to overlap with the 'triple oscillation' *ca.* 2,800-2,600 cal BP (O'Brien *et al.*, 1995; van Geel & Renssen, 1998) which marks the convergence of the 1,500-year 'Bond cycle' (Bond *et al.*, 1997), the 2,600-year cycle in the haline/dust record of GISP2 (O'Brien *et al.*, 1995) and rises in atmospheric ^{14}C production as measured in tree rings (Stuiver & Brauzinas, 1993) and a peat bog in the Netherlands (Kilian *et al.*, 1995; van Geel *et al.*, 1996). The apparent disparity amongst the Wester Ross peat bogs themselves and also with the Eastern Sutherland palaeoclimate records (Smith, 1998) is intriguing, since the change *ca.* 2,600 cal BP is inferred to have been an abrupt, high magnitude and potentially global event (*cf.* van Geel & Renssen, 1998).

There appears to be better agreement between the Uamh na Tartair (Baker *et al.*, 1995) records and the rise in lake level at Achany Glen (Smith, 1998). However, Dugmore *et al* (1999) have dismissed the Hekla 3 connection and argue that human impact is a more likely cause, with woodland clearance by people resulting in the rise in water table observed in the speleothem and peat records. Rises in lake level are not widely recorded across the UK at this time, and Scottish lochs in particular appear to be unaffected (*cf.* Yu & Harrison, 1995). The rising lake level in Achany Glen, whatever the cause, is not interpreted as related to the Hekla 3 eruption nor is it considered to have a causal relationship with the abandonment of the settlements in Achany Glen *ca.* 1000 BC (*cf.* Tipping & McCullagh, 1998).

At the Loch of Winless, Caithness, human impacts are apparent from *ca.* 2,500 ^{14}C BP and continue until 1,800 ^{14}C BP (Peglar, 1979). Unfortunately, the beginning of this phase of human activity falls into the radiocarbon plateau, and calibrates to 790-490 cal BC (2,740-2,435 cal BP). Whilst it is tempting draw a relationship between the climate changes *ca.* 2,700 cal BP recorded in NW Scotland (above), other

evidence of regional climate change and the expansion of human activity at the Loch of Winless, the chronology remains too imprecise. The relationship between climate changes inferred from the regional records above and the lake level changes recorded in Achany Glen and settlement are also ambiguous. Although the archaeological record indicates abandonment by 1000 BC, the pollen record indicates that grazing continued for another *ca.* 800 years (Smith, 1998; Tipping & McCullagh, 1998). In the west, at Lochan an Druim, Birks (1980; 1993) recorded phases of substantial woodland clearance and agricultural activity starting *ca.* 2,980-2,740 cal BP (1030-800 cal BC) and lasting until *ca.* 2,370-2,120 cal BP (420-170 cal BC).

The *ca.* 1,400 cal BP 'Dark Age' climatic deterioration (Blackford & Chambers, 1991) does not appear to recorded in northern Scotland, although the preceding period, 'The Little Optimum', is apparent as a shift to drier conditions in the Wester Ross peat bogs. The three peat bogs from Wester Ross record a significant shift to drier conditions after *ca.* 1,500 cal BP (Anderson, 1998). Neither of these change are conspicuous in the palaeoclimate records from Caithness (Charman, 1990) or Achany Glen (Smith, 1998). Palynological evidence from Achany Glen indicates continued activity. Changes consistent with LIA cooling are also recorded from shorter records, but like the Dark Age climatic deterioration does not appear to have made a substantial impact on the longer records of northern Scotland. Two sites from Wester Ross recorded shifts to wetter conditions between *ca.* 940 and 760 cal BP which although slightly earlier than expected, might only represent a lack of precision in the radiocarbon chronology (Anderson, 1998). Substantial rises in lake level are recorded in lakes in Scotland from 1,000 BP (Yu & Harrison, 1995). Two 2,500-year records of precipitation and temperature from a speleothem and a peat profile in NW Sutherland recorded significant wet shifts at *ca.* 500-600 cal BP and 150-400 cal BP (Caseldine *et al.*, 2000).

With the regional context of vegetation history and climate change it is now possible to narrow the focus to archaeological and palaeoecological evidence from the Strath of Kildonan.

Conclusions

The evidence presented here for climatic variability and its causes during the Late Holocene is by no means exhaustive, but has considered the key types of data, how they are connected and how they are used. Specific climate 'events' have been highlighted along with the ways in which different strands of the palaeoclimate record have been drawn together towards elucidating the mechanisms governing the switch from one climate state to another. The data have been evaluated and indicate frequent re-organisations of the climate system involving aspects of the oceans, atmosphere, cryosphere and lithosphere. Humans, it is argued, are well adapted to frequent, *ie.*, predictable, oscillations, where as infrequent, or unpredictable, large magnitude changes or jumps to a new climate state might prove more challenging (Dincauze, 2000; McIntosh *et al.*, 2000; Sherrat,1997). With this in mind, it is important to be able to distinguish between oscillatory and 'step-like' behaviour in proxy climate records in order to evaluate the potential effect on people (Dean, 2000).

This analysis of North Atlantic climate and British weather has shown that contrary to beliefs that 'ice core data is not relevant to the climate of Britain' (*cf.* Turner, 1981; Chapter 1), understanding the regional climate system and adjustments within it has significance for archaeological research in Britain. Palaeoclimatic reconstructions encompassing a variety of spatial and temporal scales from various locations in the North Atlantic region indicate highly variable climate behaviour during the Late Holocene. Some of this variability is clearly expressed in terrestrial climate records from tree rings and peat bogs. It has been demonstrated that there is overlap between some records of palaeoclimate change and the inferred climatic deteriorations at 1200-900 BC (Burgess, 1980; 1989) and 850 cal BC (van Geel *et al.*, 1996, 1998), each of which is argued to have had widespread catastrophic consequences for human populations during the European Later Bronze Age. However, the timing, magnitude and spatial expression of these changes are, in general, poorly resolved. In particular, forcing mechanisms and links between different aspects of the climate system remain controversial. Lack of quantification concerning many types of proxy records, including peat humification data, makes it difficult to accurately assess the potential impacts of past climate variability on humans.

Despite certain limitations inherent in proxy climate reconstruction, this analysis has shown that an appreciation of the spatial as well as temporal variability inherent in 'climate change' should influence how we formulate approaches to understanding past interactions between humans, environments and climate. While accurately and precisely reconstructing interactions between humans and climate at inter-annual scales in prehistory is likely to remain impossible in all but the most fortuitous circumstances, climate variability at these scales are least likely to induce significant and lasting cultural adjustments. The understanding of climate change on decadal, centennial and millennial scales – the scales most likely to 'surprise' humans and stimulate adjustments -- is rapidly improving, stimulated, in part by a desire to understand the human dimension of climate change towards predicting the impact of future changes (Overpeck, 1995). This discussion has shown that generalising about the impacts of climate change on people is more problematic than usually acknowledged. The question remains: does climate always operate at the macro-scale of human experience, or are impacts predominately context specific, a complex interaction of climate, environment and culture?

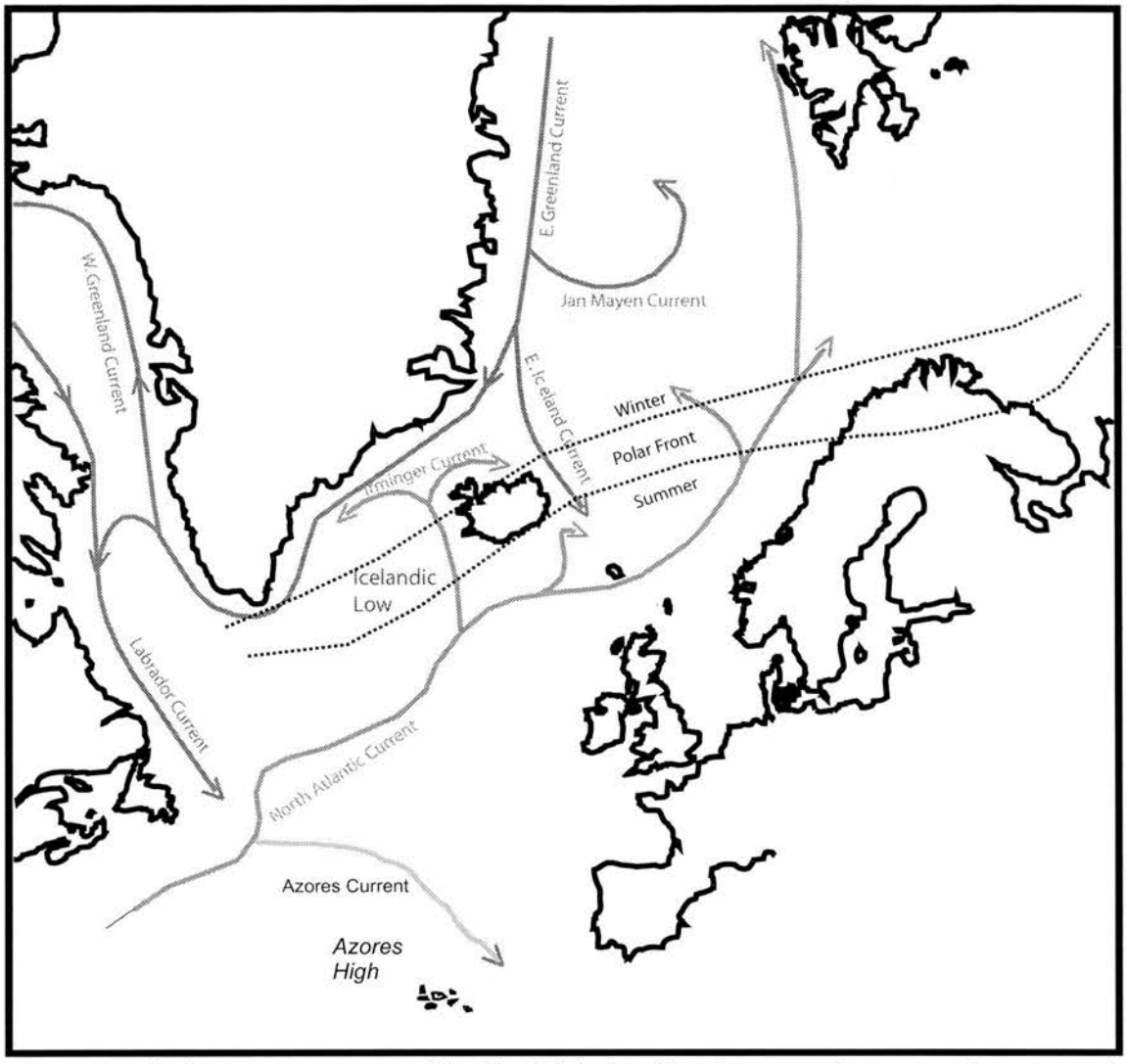


Figure 2.1. Surface ocean currents of the North Atlanic. Also shown are the present day seasonal positions of the polar front and the general location of the Icelandic High and the Azores Low.

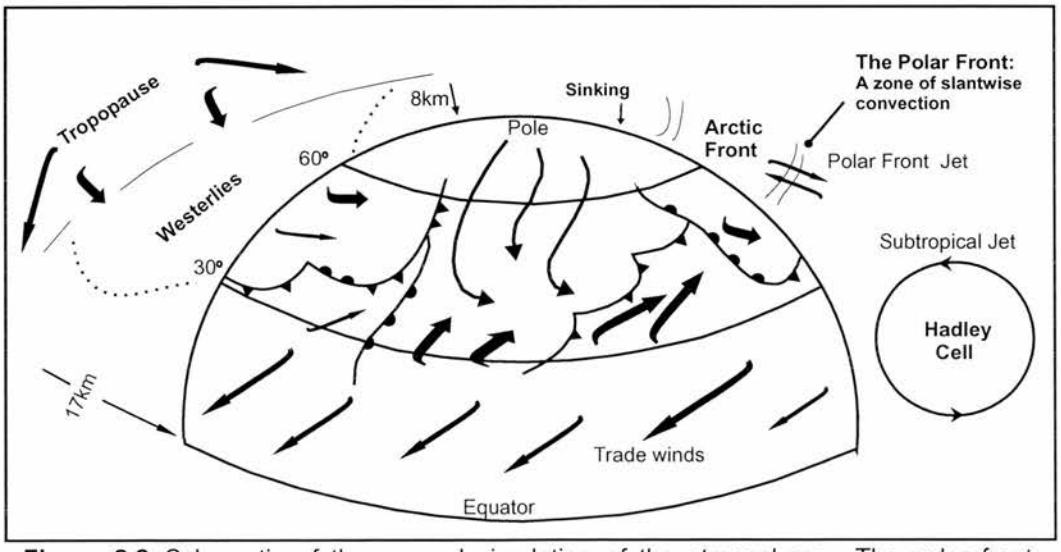


Figure 2.2. Schematic of the general circulation of the atmosphere. The polar front is a transitional boundary between cold high latitude tropospheric air, sinking and flowing toward the equator and warmer subtropical air, which is rising and moving towards the pole. The climate of the British Isles, and the general circulation of the atmosphere, is dependent to a large extent on the synoptic systems which travel through the latitudes where the polar front is positioned. Redrawn from Davies *et al.* (1997).

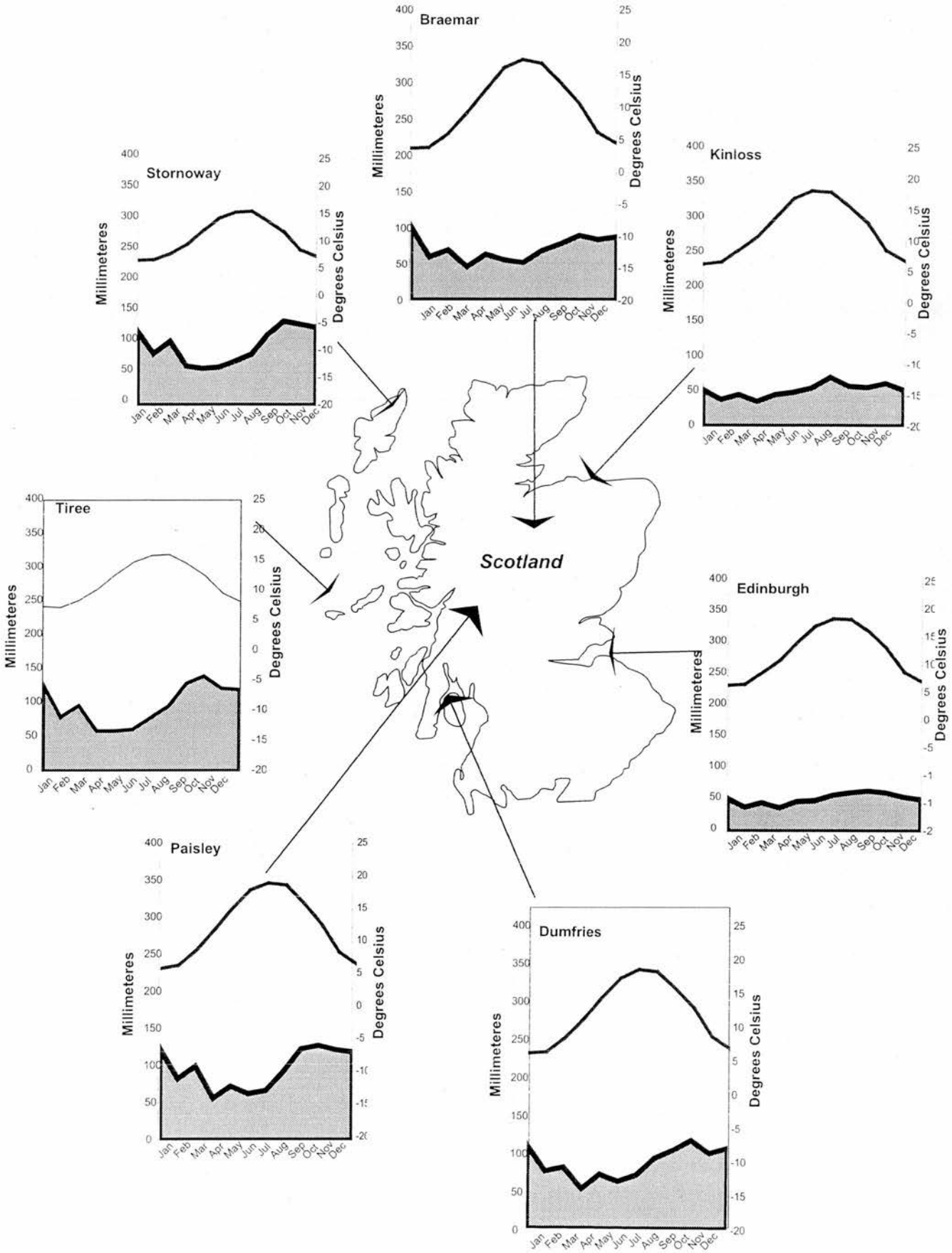


Figure 2.3. The Weather of Scotland. Graphs illustrate the average monthly precipitation at each station for the period 1961-1991. Temperature is indicated by the solid line and precipitation by the filled areas at the bottom of the graph. Of note are features such as the steep seasonal temperature and precipitation gradients between inland, upland areas such as Braemar and Stornoway compared to east coast locations such as Edinburgh and Kinloss. Data courtesy of the Met Office (www.met-office.gov.uk/climate/uk/location/scotland/index.html).

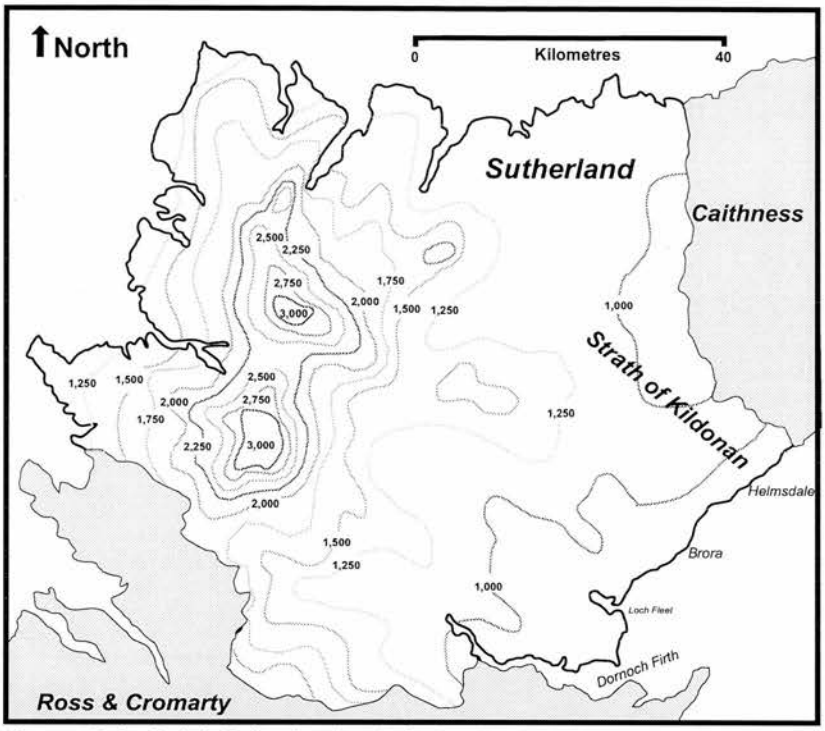


Figure 2.4. Rainfall distribution in Sutherland. Isohyets are based on the annual average in millimetres, 1941-1970. Data copyright the Met Office. Redrawn from Omand, 1981.

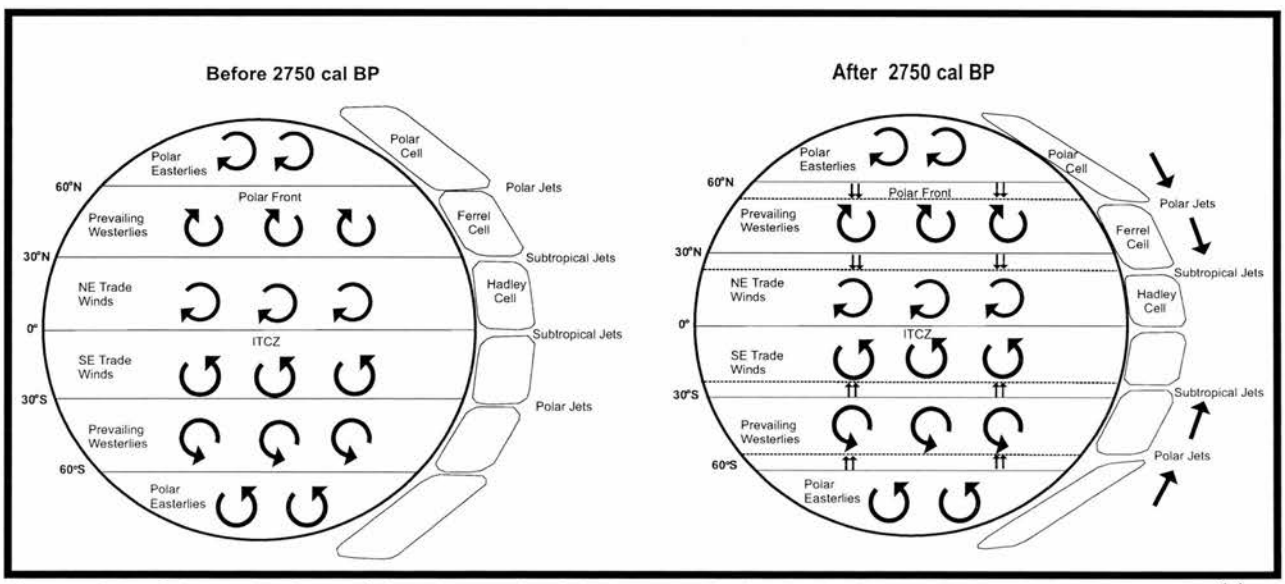


Figure 2.5. Schematic view of the change is global atmospheric circulation associated with the rise in ^{14}C. Redrawn from van Geel & Renssen, 1998.

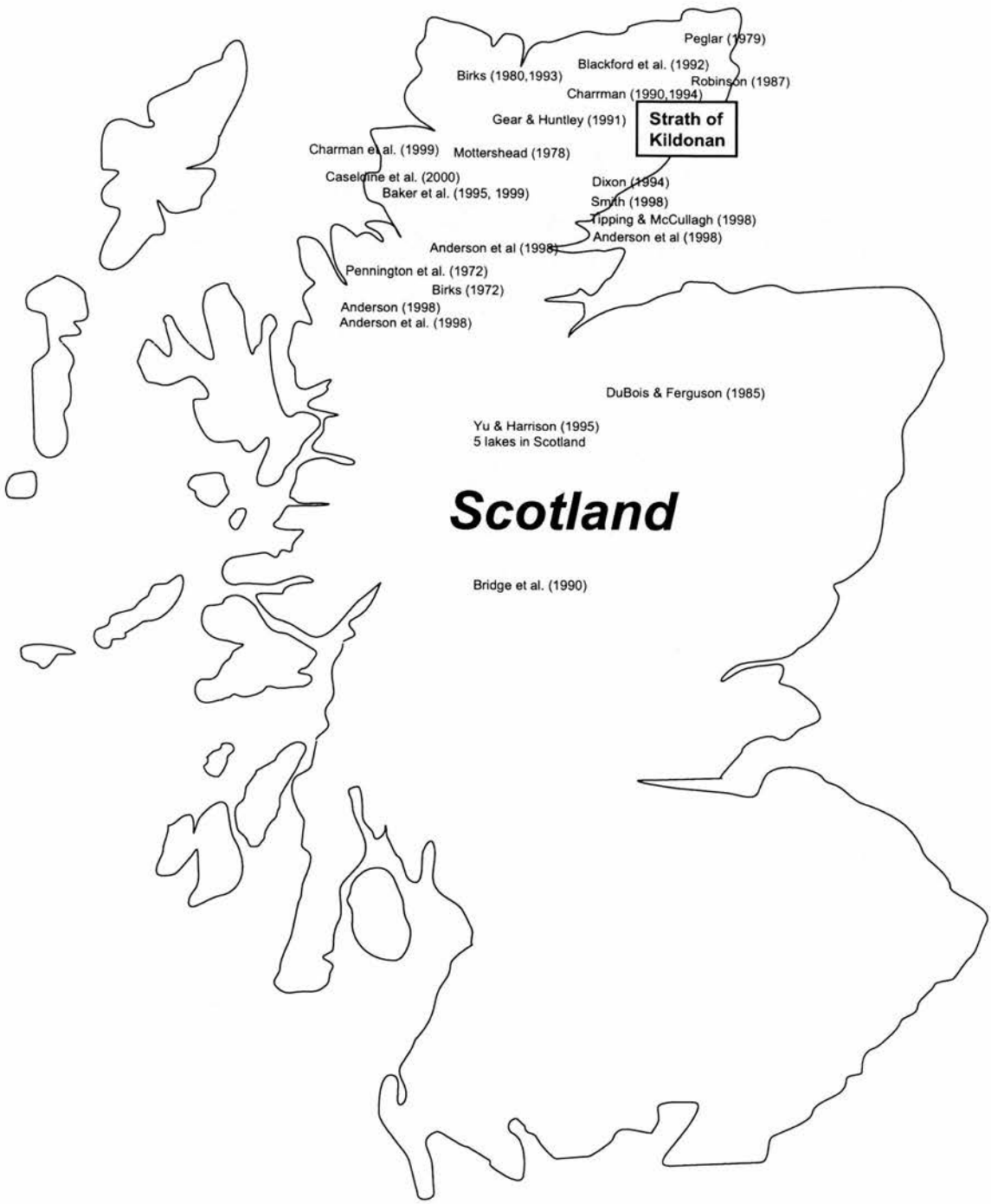


Figure 2.6. Sites of northern Scottish palaeovegetational and palaeoclimatic investigations discussed in the text.

Chapter 3

Archaeology and Settlement in northern Scotland During Later Prehistory.

"Antiquities are history defaced, or some remnants of history which have casually escaped the shipwreck of time."

Francis Bacon *The Advancement of Learning* (1605)

Introduction

This chapter is a general discussion and analysis of settlement archaeology in northern Scotland during later prehistory. Firstly, the chapter will introduce and describe basic elements of landscape archaeology in Scotland such as the ubiquitous round-house known commonly as the hut circle. The current understanding of how different elements of the cultural landscape, *eg.* hut circles, burnt mounds, field systems, functioned together or separately and how the cultural landscape evolved through later prehistory will be described. Secondly, the chapter will consider the artefactual record of northern Scotland and how material culture and social reproduction has contributed to the formation of the archaeological landscape. The chapter will conclude by analysing the different ways in which the interpretation of settlement patterns and material culture have been used to formulate models of settlement change and its relationship to ecological thresholds.

Elements of the Archaeological Landscape

Hut Circles

It is almost impossible to begin a general discussion of later prehistoric Scotland without mentioning the Strath of Kildonan from the outset. Some of the earliest and only investigations of 'hut circles' (Figure 3.1) began in the Strath in the early 20th century when Curle (1910; also RCAMS,1911) (Figure 3.2) investigated a handful of hut circles and souterrains in the upper Strath. Whilst he was able to produce detailed

descriptions about the structures, the excavations themselves yielded very little in the way of artefacts or chronological information.

McCullagh (1998:2) notes that "...full excavations...have been so rare that each site has become either a 'type-site', *e.g.*, Kilphedir (Figure 3.2) in the Strath of Kildonan (Fairhurst & Taylor, 1971) or has remained an enigma, such as [Upper] Suisgill, also in the Strath of Kildonan (Barclay, 1985)". Until the mid-1980s the only excavated and radiocarbon dated hut circle settlement in Scotland was Kilphedir, in the Strath of Kildonan, which implied a mid- to late first millennium BC occupation (Fairhurst & Taylor, 1971). The long term reticence towards the systematic excavation of hut circles might be related to the belief expressed by some archaeologists that these structures represent the squalid hovels of peasants and were unworthy of serious investigation (Gresham, 1963).

In Britain, much of the discussion concerning later prehistoric settlement is centred on round houses (Figure 3.1). Prior to the Kilphedir excavations, Beaker fragments were known to be associated with hut circles in Ayrshire (Figure 3.2), providing a relative early second millennium date (*cf.* Childe, 1935). But hut circles with souterrains located in Aberdeenshire and Sutherland, along with the radiocarbon chronology established at Kilphedir led to the persistent belief that hut circles were an Iron Age phenomenon (Halliday, 2000). Not until the excavations at Cúl a'Bhaile, Jura (Stevenson, 1984), An Sithean, Islay (Barber & Brown, 1984), Arran (Barber,1997) and Lairg, Sutherland (McCullagh & Tipping, 1998) (Figure 3.2) was it demonstrated that hut circle construction spanned a period stretching from the early second millennium BC through the early first millennium AD (Cowie, 1998; Halliday, 2000; McCullagh, 1998).

Recent work on other northern hut circles also supports a wider chronological range. Two radiocarbon dates from the same context in Structure V, a hut circle excavated at Cnoc Stanger, Sutherland (Figure 3.2) yielded ages of 2910±60 BP and 3620±95 BP; a floor sample from Structure II was dated to 3350±90 BP (Mercer, 1996). The discrepancy in dates is thought to be a result of 'old wood' incorporated into Structure V, possibly through the recycling of structural timbers (Mercer, 1996). The

excavations at Lairg indicated that hut circle occupation began *ca.* 1800 BC and ended around 800 years later (McCullagh & Tipping, 1998).

Round house forms, although recognised in many parts of the 'Bronze Age world', are most commonly found in Britain and southern Italy (Harding, 2000:28). Despite their relative ubiquity, particularly in upland landscapes (Figure 3.3), they have only been systematically investigated for the past three decades (Halliday, 2000; Harding, 2000). Blood (1989) notes that the term 'hut circle', with its pejorative connotations, is overly simplified and subsumes a remarkable variety of forms. Curle (1911) identified 4 main types during his investigations in the Strath of Kildonan (Table 3.1). Thorneycroft (1932) first coined "Dalruzion" to describe the typical double-walled hut circle, after the type site in Perthshire, Scotland (Figure 3.2). Harris (1984) subsequently defined 8 classes of hut circles in SE Perthshire. In Sutherland and Caithness, Mercer (1980; 1985) identified 16 morphological types. O'Sullivan (1998) notes that whilst a correspondence between the house forms excavated at Lairg and Mercer's northern round house typology is apparent, it is emphasised that these types represent only the final stages in the formation of the structure, not the original and intended design.

Although the majority of known hut circles at present appear to have been constructed with stone foundations, the over-arching, presumably timber structure of the house remains obscure. Excavations from Lairg revealed enough evidence of post-holes to allow some limited reconstruction (*cf.* O'Sullivan, 1998). At Kilphedir, there was evidence of turf wall construction and fragments of burnt wattle were recovered from the stone foundation (Fairhurst & Taylor, 1971). Hut circles often exhibit 'embellishments' which can take various forms. Additions such as thickened wall terminals, internal cells and double walls may represent architectural differentiation on the grounds of social status or, although not apparent from the current chronological framework and keeping in mind O' Sullivan's (1998) *caveat*, temporal development of style (Cowley, *unpub*; Fairhurst, 1971; Harris, 1984).

The significance of the orientation and shape of the later prehistoric round house has also provoked discussion. In an intensively surveyed area of upland SE Perthshire, the majority of hut circle entrances face E or SE (Harris, 1982). The apparent

Table 3.1 Northern Scottish hut circle typologies.

Curle (RCAMS, 1911):

Type 1: Oval or pear-shaped; stone/turf walls; 6-10m diameter. Found in association with cultivation or cairnfields. Entrances in three basic forms: 'normal'; a) claw type one flank extends and partially surrounds the other to create a 'porch'; b) expanded or club shaped which elongates the entrance passage and sometimes contains other features.
Type 2: Circular huts, stone built with courses or orthostats; not regularly associated with field systems.
Type 3: Mounds
Type 4: Circular enclosures "hollow walled huts", no evidence of entrance, often a gully outwith the enclosure bank.

Mercer (1985), Sutherland and Caithness :

Type 1:
Type 2: Large accumulated amorphous structures; burnt mounds.
Type 3: Small-medium circular enclosures.
Type 4: Unenclosed platforms.
Type 5: Small cellular structures.
Type 6: Platform with stone superstructure.
Type 7: Medium size with swollen terminals.
Type 8: Large with inner wall groove.
Type 9: Large with inner wall groove.
Type 10: U-shaped enclosure with wide-entrance.
Type 11: Curle's 1b, medium-large.
Type12: Medium –large sub-circular, built in segments, simple entrance.
Type 13: Curle's 1a
Type 14: Enclosures with broad, flat backs and no apparent entrance.
Type 15: Complex entrance (spurred); associated with burnt mounds.
Type 16: Lobate multicellular structures; includes wags.

Harris (1984), Perthshire:

Type 1: Single walled.
Type 2: Double walled. "Dalruzion" (Thorneycroft, 1932:187).
Type3: Tangential single.
Type 4: Tangential double.
Type 5: Tangential single-double.
Type 6: Integral single.
Type 7: Integral double.
Type 8: Platform.

consistency of hut circle orientation to the E-SE throughout Britain has given rise to some suggestions that the round-house represents a microcosm of the Universe, with an east-facing entrance to greet the sun each morning; the form of the house becoming an embodiment of the cycle of light and darkness (Parker-Pearson, 1996). In more general terms, southern British evidence has been used to argue for the importance of ideology and cosmology in the organisation of domestic space (Hill, 2000). Or as Harding (2000:30) succinctly summarises: "...a reflection of prevailing cosmology, not the prevailing wind."

Survey evidence from northern Scotland indicates that only 40% of the hut circles in Sutherland are oriented in an easterly direction, and even fewer, 35%, in Caithness (Howard, 1983). These contrasting patterns of settlement orientation may present an intriguing alternative for further investigation. In terms of shape, the round house contrasts both to the Neolithic rectilinear forms which preceded it (*cf.* Barclay, 1997) and the return to these forms in the first millennium AD (Ralston & Armit, 1997). A review by Rafferty (1987) of the archaeological notion of 'sedentariness', highlighted earlier work which suggested that round house forms, in a variety of ethnographic and archaeological contexts, are more common in non- to semi-sedentary societies whereas rectilinear structures are more common to settled societies because of the easier addition of extra rooms. The 'keyhole' shaped plans associated with some northern structures (Mercer, 1985; RCAHMS, 1993), and the additions of guard cells and annexes may reflect both a later period of construction, or refurbishment which could be related to wider changes in settlement organisation. If suggestions that hut circles were only occupied for brief periods of time (Fairhurst & Taylor, 1971; Halliday, 2000) is correct, the addition of rooms and annexes might reflect a change to a more sedentary lifestyle. This needs further investigation.

Fire seems to figure frequently in the occupation histories of hut circles. The placement of a quern face-down at the back of House 4 and the absence of any other significant artefactual material might indicate that the catastrophic burning of the house was deliberate (although post-conflagration scavenging of artefacts was not ruled out) (Dalland & McCullagh, 1998). Houses 1 and 2 at Lairg also appear to have suffered burning at some point. A hut circle from Tormore, Arran, interpreted as

a possible storehouse containing cereals and wood, was also destroyed by fire (Barber, 1997) as were the hut circles at Cnoc Stanger, Sutherland (Mercer, 1996) and Cyderhall, Sutherland (Pollock, 1992). Hut circles, with their timber roof supports and thatched roofs might have been vulnerable to fire. However, considering the discussion of ritual abandonment in Chapter 1, the possibility that these fires represent deliberate acts of closure to periods of occupation should not be dismissed. Destruction of houses by fire does not appear to necessarily result in permanent abandonment of the house site; as later structures are often superimposed on the sites of the burnt houses (*eg.*, Barclay, 1985; Dalland & McCullagh, 1998).

While the term hut circle may imply these structures were used primarily as dwellings, increasingly evidence from excavation indicates that the uses of hut circles varied, and that the functions of individual houses might vary over time (Dalland & McCullagh, 1998). Houses at Lairg were damaged by the imposition of later cultivation, whilst another may have been turned into a byre (Dalland & McCullagh, 1998). And as noted above, one of the Tomore hut circles may have functioned as a storehouse (Barber, 1998). Hut circles, whether singly or in clusters, are frequently be found with structural remains associated with agricultural production, *eg.*, clearance heaps, lynchets, stony banks, walls, cord rig or ditches (*cf.* Halliday, 1993), sometimes organised into recognisable field systems. What remains in most areas, however, is a palimpsest of agricultural and other activities spanning centuries, if not millennia, and untangling the various contemporary agricultural activities and site formation processes is an ever present challenge (Halliday, 2000).

Field systems

In parts of the British Isles, with probably the most well known example being the Dartmoor Reaves (Fleming,1978, 1988), highly organised complex field systems emerged in parts of Britain during the earlier Bronze Age. These were arrangements of enclosed fields separated by slow stone walls (reaves) partitioning the land into territories, separating open moorland, upland and lowland valley areas. Within these larger areas, more reaves delineated smaller, individual field systems (Figure 1.1). By contrast, the open, unenclosed upland agricultural landscapes of upland and northern Scotland have remained distinguishing features up to the present day (Bil, 1990) (Figure 1.2). Prehistoric examples of field systems enclosed by four walls are

unknown (Halliday, 1993), the closest potential example, a three walled field system from An Sithean, Islay, was discovered to be three different periods of construction (Barber & Brown, 1984).

There are occasional examples of more formal arrangements, reminiscent of southern British examples, in Scotland, but by far, these appear to be in the minority, and are most frequently associated with lowland areas. At Tulloch Wood, Morayshire (Carter, 1993), a lowland, coastal site (Figure 3.2), more formalised, coaxial field systems along the lines of those known from southern Britain, have been recorded. At Tulloch Wood, near the margins of modern day agricultural production, it appears that clearance and arable activity began in the Early Bronze Age, and that the Later Bronze Age marks a period of substantial reorganisation of the landscape and the construction of a coaxial field system (Carter, 1993). At Rattray, another coastal site in Morayshire, a possible fence upright belonging to the late 2nd millennium BC was uncovered, a age consistent with the flat-rimmed pottery found at the site (Murray *et al.*, 1993). The excavation also revealed a section of burnt hurdling, which was interpreted as a trackway across the fields rather than fencing.

A broad classification of hut circle settlements and field systems in northern Scotland has been developed (Cowley, 1998; RCAHMS, 1993). There are three groups (Figure 3.4):

- **Group 1**. These are simple hut circles, usually with little or no evidence of embellishment or phasing. They are isolated from other monuments (*eg*, burnt mounds, other hut circles, etc.) with no evidence of cultivation or other obvious agricultural activity. Although reflecting a wide geographic distribution, they are most likely to found at higher altitudes (in the Strath of Kildonan, this is *ca.* 250m OD, but the highest altitude hut circle in Scotland is found at Dirnanean, Perthshire, at *ca.* 500m OD (RCAHMS, 1990).
- **Group 2.** This group includes hut circles occurring in small clusters, and individual huts may exhibit some evidence of refurbishment and/or embellishment. These huts may be situated amongst scatters of cairns and fragmentary banks, but not with formal field systems or plots. Widely distributed, but most frequently found between 150-200m OD.

- **Group 3.** Large clusters of hut circles surrounded by formal plots and field systems defined by lynchets and/or banks. Hut circles in this group most often reflect signs of phasing or embellishment. These are located mostly below 150m OD.

The altitudinal distribution is thought to reflect a gradient of marginality. Group 1 settlements may represent the expansion of settlement into the upland during a period of good climate and population pressures. Settlement may have ebbed and flowed along this altitudinal gradient as conditions allowed, but with peripheral Group 1 and 2 settlements expanding intermittently around the core of Group 3 settlements (Cowley, 1998; RCAHMS, 1993)

Cows and Ploughs: The Later Prehistoric Agricultural-Economy

How the land was worked and the products it yielded are less in evidence than how it might have been organised, although some broad patterns of activity can be inferred from the latter. The small, irregular plots which generally characterise the agricultural landscapes of later prehistoric Scotland, in comparison to the extensive 'Celtic fields' of southern Britain, may reflect cultivated foods used to supplement diets mainly based on animal products (Halliday, 1993). It was suggested that the small field plots found at Lairg might represent 'garden plots' where vegetables, including 'famine foods' such *Chenpodium album* were tended, perhaps in rotation with cereals such as barley (Holden, 1998; Tipping & McCullagh, 1998). Excavation of a souterrain at Cyderhall revealed evidence of hemp and flax, possibly used to construct containers for other products; grasses and herbs; ergot was discovered, although other evidence of cereals was slight (Pollock, 1992).

Barley is the type of cereal most often recovered from Bronze Age contexts, although emmer wheat is sometimes found as well (Boyd, 1988). At Lairg, despite the wealth of evidence, it is still uncertain if cereals were locally grown and harvested at marginal settlements or whether they were imported from core areas, as either grain or as partially processed products (McCullagh & Tipping, 1998). Finds of cereal-type pollen were infrequent for the period covering the Bronze Age, and then restricted to a site investigated on the valley-side (Smith, 1998). The results of 'on-site' pollen analysis of agricultural soils suggests that cereal were not grown in them (Tipping,

1998). Crop processing products (chaff) were not found, either, but these do not usually survive well in archaeological contexts (Hillman, 1981). There were indications, however, that other processing activities, such as the drying of cereal was taking place on-site (Holden, 1998). Quern stones were also infrequent, but this may be a problem of archaeological visibility, with crop processing tools fashioned of wood rather than stone (Clarke, 1998).

The differential preservation of cord rig between field plots as a result of fallowing has been inferred (Halliday, 1993). Ard marks and rigging are associated with a number of sites, *e.g.*, Lairg (McCullagh & Tipping, 1998), Cúl a'Bhaile, Jura (Stevenson, 1984), Arran (Barber, 1997) and Upper Suisgill (Barclay, 1985). Frequent finds of stone ard points are known from the Northern Isles (*cf.* Rees, 1979; 1981), but the mostly treeless nature of these landscapes means that tools and utensils were more likely to be constructed out of stone, and conditions are biased towards their survival in these areas (*cf.* Tipping & McCullagh, 1998). On the mainland it is more likely that most tools and utensils would have been made from wood, and, again, the lack of recovered objects is mainly an issue of resource availability and preservation.

The products of practices based on animal husbandry such as manure, hides, wool, butter, cheese and meat, along with animal bones and horns, do not survive well in the acidic, dryland contexts where most hut circles are situated. Some features and structures recovered from excavation or observed during survey are thought to be related to aspects of animal husbandry. Enclosures at Black Moss, Achnacree, Argyll may have been used to control stock (Halliday *et al*, 1981). Grazing is apparent in many palaeoecological reconstructions from northern Scotland (*eg.*, Andrews *et al.*, 1985; Birnie, *unpub*; Pennington *et al*, 1972; Robinson, 1987; Smith, 1998). Where conditions allow preservation, excavations from all over the Scottish mainland and Islands indicate that cattle, sheep, goats and pigs were probably the main domestic livestock (Cowie & Shepherd, 1997). A souterrain at Cyderhall revealed ova from sheep liver fluke and whipworm, as well as fragments of cattle bone and teeth (Pollock, 1992). Two yokes have been recovered, indicating the use of animal traction. One, from Loch Nell, Argyll has been dated to *ca.* 1950-1525 cal BC, and is the earliest known (Hedges *et al.*, 1993), a second from Orkney is dated *ca.* 1516-1253 cal BC (Hedges *et al.*, 1993).

Burnt mounds

The role and significance of burnt mounds (Figure. 3.5) in the upland economies of northern Scotland remains obscure (also *fulachta fiadh*, O.Ir.) In general these features appeared in NW Europe during the earlier part of the Bronze Age and remained in use into the first millennium AD. Like the various elements of field systems, their relationship to, and place in, prehistoric economic and social life remains disputed. The function of the burnt mound, usually located near streams or other convenient water sources is now more widely accepted be a cooking place rather than a sauna (Ó Drisceoil, 1988). Typically, burnt mounds are comprised of heaps of cracked and fire reddened stones in a matrix of black soil and charcoal (RCAHMS, 1993). Their size and the amount of material associated with them indicates that they were used regularly, and may have been associated with communal feasting (Blood, 1989).

Some have cautiously suggested that burnt mounds could have functioned in relationship to other structures and merits further investigation (Russell-White, 1990). However, burnt mounds are frequently constructed on formerly cultivated ground, leading others to the suggestion that burnt mound construction and arable agricultural were mutually exclusive activities, and burnt mounds and hut circles are not related (Halliday, 2000). It is instead argued that these were the cooking places of semi-sedentary pastoralists. Old land might be rejuvenated by the temporary presence of herds of livestock, providing a temporary manuring service, allowing late re-use of the land for cultivation (Halliday, 2000). At Lairg, however, it was demonstrated that the use of burnt mounds overlapped with the occupation of the settlement. The locating of burnt mounds on poorer, boggier ground at the settlement prompted the suggestion that these 'marginal' areas were incorporated into the economic and social life of the settlement (Dalland & McCullagh, 1998).

Given the lengthy span of their use, the significance of these monuments and their role in various communities may have altered substantially over time. If, at times, burnt mounds were sites for the preparation of communal and ritual feasting events, they may have acted as foci for the renewal and strengthening of local kinship links and alliances. At other times, they may have provided a mere utilitarian resource, a

means to process large amounts of food efficiently, for example after calf slaughter (*cf.* Clutton-Brock, 1981; McCormick, 1998). Rarely are they associated with any significant artefact finds and, although it has been possible to broadly relate periods of use to other structures and features (*eg.* Lairg), the nature of radiocarbon dating limits the precision with which this can be done.

Souterrains

Souterrains first began to be constructed during the Iron Age (Figure 3.6). They may be free standing, or may be linked with individual hut circles, where entry to the souterrain is gained through the interior of the hut circle. These underground passages are thought to have been used primarily for food storage (Haselgrove, 1999). In particular, they may have been the storehouses of powerful, high status families who inhabited brochs (Sharples, 1985) or they may have stored the agricultural surplus for entire communities (Watkins, 1981). The excavation of a souterrain at Dalladies, Kincardineshire (Watkins, 1978) and of a hut circle and souterrain at Cyderhall, Sutherland (Pollock, 1992) both revealed evidence of timber uprights, implying the former presence of an above-ground structure.

Brochs

The subject of brochs, drystone tower houses which emerged in later Iron Age, is the focus of a wide literature debating their origins and development and will only be considered briefly here. It has been argued that the trend from simple hut circles towards embellishment and more massive constructions, particularly double walls, represents a later horizon of hut circle construction, antecedents to the complex Atlantic roundhouse types which includes brochs, duns and galleried duns (Armit, 1990; Cowley, *unpub*; Fairhurst, 1984; Mercer, 1985). At one time it was believed by some that brochs, most commonly found on the northern Atlantic coast of mainland Scotland and the northern and Western Isles (Figure 3.7), arrived in Scotland from England as the result of a diffusionist process (Armit & Ralston, 1987). Recent work has demonstrated, however, that the development of broch architecture spanned several centuries and was an indigenous phenomenon (Armit, 1990, 1991; Hedges, 1987). The evolution of simple hut forms into more complex architectural expressions has been linked by some to changes in the agricultural economy during the first millennium BC (Hedges, 1987), and specifically the use of iron and the

adoption of the rotary quern over the saddle quern, which had been in general use since Neolithic times (Armit, 1990; 1991).

The development of complex Atlantic roundhouses was initially linked to a period of climatic amelioration in the later first millennium BC, but this has been questioned and the alternative perspective is that they emerged out of a situation of economic stress (Armit, 1990;). Their purpose as purely defensive structures (Armit & Ralston, 1997) has also been questioned. Others argue that the origins of some aspects of broch architecture may lie in the emergence of competition between family groups and as medium through which power and control was legitimised (Foster, 1989). It has been speculated that less powerful members of society may have continued to live in more traditional hut circle dwellings, partially based on later first millennium BC radiocarbon ages obtained from Kilphedir (Hingley, 1992). However, as with burnt mounds, the relationship of brochs to other structures has not been thoroughly investigated (Armit, 1990; Hingley, 1992).

It is suggested that the wider resource base of Caithness, which includes a higher proportion of low lying areas, a broad coastal plain and relatively free access to the sea were able to support increasingly large populations as the first millennium BC progressed, in contrast to the more thinly populated areas of Sutherland, where uplands dominate (Figure 3.7) (Cowley, *unpub*). The developments that characterised Caithness in the late first millennium BC may have laid the ground work for the political and economic structures which allowed the area to assume an increasing degree of political authority during the first millennium AD (Armit, 1989). However politically marginal Sutherland may have become, it had at its disposal control of valuable resources such as timber and grazing land (Cowley, *unpub*) which could have played a central role in the political economy of the region and provided some degree of autonomy and power.

Hillforts

A discussion of hill forts in northern Scotland sits comfortably in neither a chronological or typological breakdown of settlement. The knowledge of hill forts in Scotland is limited mostly to survey data (Figure 3.8), with exceptions such as Traprain Law, East Lothian or Eagle Law in the Moorfoot Hills and Tap O'Noth in

Aberdeenshire but none of the Caithness or Sutherland hill forts has been excavated. It has been speculated that occupation of Ben Griam Beg, by far the largest and highest (*ca.* 420m OD) hill fort in the north, may extend back to the Neolithic, but this is only a supposition based on the degree of soil creep and peat growth (Ralston & Smith, 1982). The site was later re-assessed in terms of new data from Tap O'Noth, Aberdeenshire which has an estimated radiocarbon age of 2160±400 BC (Sanderson *et al.*, 1988), also supporting a longer time span for northern hill fort occupation (Mercer, 1991),.

It is no longer believed that hill forts served a primarily defensive function, given the small scale of their defensive features (Ralston & Armit, 1997). In continental Europe they may have marked territorial boundaries and controlled exchange (Kristiansen, 1998). Similarly, it has been suggested that English examples functioned as re-distribution centres (Cunliffe, 1984). It has also been suggested that, in southern Britain, hill forts may have dominated pastoral areas (*ie.*, uplands); whilst areas of primarily arable farming (*ie.*, lowlands) are characterised by high metal consumption (Rowlands, 1984).

Figures 3.8. and 3.9 demonstrate the potential for further investigation of similar relationships in northern Scotland. There are two interesting features in this distribution of hill forts and hoards as it is currently known. Firstly, the orientation of the hill forts and hoards is parallel to the narrow, fertile coastal strip of eastern Sutherland (Figure 3.9). The hill forts are generally located on first most prominent point inland from the sea, and usually along a sea loch or river and appear to dominate Sutherland's limited inland areas of more fertile soils. Their location near the boundary of modern day Sutherland and Easter Ross also marks the division between an extensive area of fertile lowlands that stretches down the eastern coast and into Morayshire, from the mostly rugged and upland landscape of Sutherland.

The distribution of hill forts and hoards may potentially mark 'buffer-zones' between territorial units (*cf.* Brun, 1993; Kristiansen, 1998), perhaps between upland areas and their coastal and lowland counterparts. Alternatively, or in addition, it might also represent territorial division of the more extensive agriculturally rich lands to the south, a cereal-growing 'core', from 'marginal' upland areas, where stock rearing

formed the basis of the economy (*cf.* McCullagh & Tipping, 1998). Ben Griam Beg to the far north is enigmatic outlier. At present, however, the general lack of substantive information about hill forts and hoards prevents the inference of any reliable and meaningful relationships between these phenomena and other elements of the archaeological landscape (*cf.* Hingley, 1992).

Artefacts and Exchange: Aspects of Social Reproduction in Northern Scotland

The artefactual record of northern Scotland is neither as rich or as varied as other areas of Britain and a particular shortcoming is the lack of reliable contextual information for many objects that are known. McCullagh (1998:5) draws special attention to "archaeologically significant" finds such as an elaborately decorated flint macehead discovered near Bonar Bridge and the early Bronze Age Migdale hoard (Coles, 1969) (Figure 3.8). In the early part of the 20th century a gold hoard of finished and unfinished cup-ended ornaments was discovered at the Heights of Brae, Ross and Cromarty (Clarke & Kemp, 1984). In light of the recent re-assessment of the objects in the hoard, it was concluded that the pieces dated from the 8-7th centuries BC. Usually thought to be objects of Irish origin and manufacture, the presence of unfinished pieces was considered evidence of their local manufacture, rather than importation. There are other examples of metalwork finds in Sutherland which are summarised in Figure 3.10.

The presence of the hoards raises many questions. Was such wealth controlled by individuals, families or communities (*cf.* Clarke & Kemp, 1984)? Gold occurs naturally in Sutherland, in the Strath of Kildonan, both in the Helmsdale River and the smaller side-burns of Kinbrace, Suisgill, Kildonan, Craggan and Torrish. The famous 'gold rush' of 1868-1869 left its mark on the valley in the place name 'Baile an Òr, or 'Gold Town', at the foot of the Suisgill Burn (RCAHMS, 1993). Is it possible that this source of gold was discovered briefly in prehistory? In the absence of more reliable contextual information, the economic, political, social, and possibly ritual, significance of the hoards and their placement in specific areas remains continues to be obscure

Although the tendency is to focus on objects that are "archaeologically significant", perhaps in terms of their remarkable craftsmanship, artistic design, or just in terms of pure wealth, these objects represent only a single facet of prehistoric life. There are the sometimes cruder or less ornate objects, both decorative and utilitarian, that are also likely to enhance our understanding of 'everyday life' (Hill, 2000). Sheridan *et al.* (1998) described objects of shale, mostly bangles and finger rings, recovered from Lairg. Similar materials are often described as jet, lignite, cannel coal, as well as shale; these are different phases of what is otherwise broadly known as coal, and the terms are often used interchangeably and indiscriminately. Despite difficulties in tracing such materials, certain characteristics such as pyrite inclusions can provide a relatively secure basis for identifying a particular source. Petrological analyses of the material from Lairg indicated that the material probably originated along the east coast of Sutherland, just north of Brora (Sheridan *et al.*, 1998) where there is Jurassic age outcrop of shale (Gibson, 1922). Working debris was found at Lairg, suggesting that exchange sometimes may have been in the form of raw materials rather than finished pieces. The origins of the material, along with other aspects of the artefact assemblage, such as the juxtaposition of finely crafted beads against a more amateurish copy, may indicate localised production, based either on the travel of 'design ideas' or itinerant specialist craft workers (Sheridan *et al.*, 1998).

Talc, or steatite, temper is frequently found in ceramics from northern Scotland. From the excavation of a hut circle at Rhiconich, Sutherland (Donnelly, 1997) (Figure 3.2), Lairg (Dixon & MacSween, 1998), Cnoc Stanger (Mercer, 1996) and several other excavations in northern Scotland. At Lairg, pottery assemblages with steatite inclusions were recovered from contexts broadly covering the period 1800-1200 BC (Dixon & McSween, 1998). The assemblage from Lairg indicated an increasing use of the material over time. The pieces may have been imported as finished, or because of the coincidence of the introduction of steatite with new styles, and the re-location to Lairg of people more familiar with the use of steatite as a temper (Dixon & Mac Sween, 1998).

Settlement Organisation in Later Prehistory: Ideas and Evidence

It has long been speculated that upland settlement may have formed one part of a complex regional economy where lowland and coastal areas depended on these settlements for their products (; Fowler, 1978; Rowlands, 1980). Again, whilst the focus was initially on the southern British experience, others have argued that exchange systems of a similar nature were in place in northern Britain as well (Young & Simmonds, 1995; Young, 2001, 2002). The Lairg settlement, where evidence for on-site cereal production was intermittent and tenuous, may have acted as an upland, livestock producing 'periphery' to some unidentified, lowland, cereal-growing 'core' (McCullagh & Tipping, 1998). However, this is only one level at which alliances and organisations may have operated. Within the upland and lowland spheres, co-operation and interaction may have existed a variety of spatial scales.

Models of Bronze Age Settlement

Brun and Pion (1992) found that settlement patterns in an areas of France reflected differing forms of centralised power at three general scales: 1) individual farms clusters around a monument or other symbol of community and ruled by a chief who inhabits one of the farms; 2) clusters of farmsteads centred on a village near the territorial monument; 3) similar to 2 but the territorial monument is replaced by a fortification. The type 3 settlement owed its existence to the control of long distance trade, particularly metal, and controlled the marginal zone between different cultural complexes. Fleming's (1985, 1988) model of settlement in Britain differs mainly because of the dearth of evidence of monuments which could be outward symbols of unity, territoriality and/or political control until the construction of the brochs or hill forts

Fleming (1985, 1988) considers the household (or farm) the primary level of social organisation representing families or people with close kinship ties. The next level up, are collectives of farms. These may also be characterised by varying degrees of kinship. At this level of organisation, economic activities, such as harvesting, crop processing, perhaps 'barn raising,' are carried out, there may some degree of communal land ownership, as well as distribution of agricultural products and decision-making. The third and largest level is regional, incorporating the types of links which may have facilitated activities such as territorial defence and long-distance exchange. Fleming (1985) suggests that groups settled in marginal areas will

foster long distance exchange with other groups, reciprocal relationships that might be relied upon in times of economic or environmental stress. The social aspects of settlement, he argues, must be considered, especially if economic thresholds are defined by the ecological attributes of settlement location. O'Shea (1983) believes that systems of regional exchange can be an important strategy in helping individuals and communities cope with food scarcity. Ceramics are often exchanged for foodstuffs and kinship ties can play an important role in dictating the form exchange networks take (Stark, 1994).

Both of these models, Brun & Pion's (1992) and Fleming's (1985, 1988) imply a degree of sedentariness that some argue simply does not apply to hut circle settlement in Scotland. There is a certain tension between palaeoenvironmental work, which increasingly indicates settlement continuity, or at least maintained exploitation of land *verus* evidence which others contend demonstrates that hut circle settlements were occupied at best for several decades (Halliday, *unpub*). The alternative perspective put forward is that in response to marginality, rather than deploying any complex adjustment strategies, settlements were simply abandoned (Cowley, 1998; Halliday, 1992, *unpub*). This view has it roots in the type of settlement that was initially envisioned for the Strath of Kildonan where inherent soil poverty and the absence of technology to 'improve' soils forced the practice of shifting cultivation and frequent settlement abandonment (*cf.* Fairhurst & Taylor, 1971). The notion of semi-sedentary pastoralists appropriating formerly cultivated ground for grazing and burnt mound construction (Halliday, *unpub*) can be traced back to the idea that the Type 1 settlement patterns investigated in Kilphedir could have, on a much larger scale as well, "...been produced by a small semi-nomadic population occupying the upland for no great length of time" (Fairhurst, 1971:7). Settlement may have alternated between cores and peripheries (Cowley, 1998; Halliday, 1993, *unpub*) or some groups of people may have spent their entire existence migrating through a succession of peripheral environments (Halliday, *unpub*).

At Lairg, landscape utilisation was described in terms of 'blacklands', areas of blanket peat and heather moor and islands of 'greenlands', pockets of better soils supporting fertile grassland (Tipping & McCullagh, 1998, Tipping & McCulloch, 2000). The characterisation of settlement patterns at Lairg follows closely the core-

periphery model outlined in Chapter 1 and above. However, it argues for a much more local spatial scale of core-periphery than a crude Highland-Lowland divide (*cf.* Fowler, 1978; Fox, 1932). Abandonment of settlements at Lairg *ca.* 1000 BC appears to be confined to those situated within the blacklands (periphery) with multi-period settlement restricted to the greenlands (core) (Tipping, *unpub*). However, unlike earlier suggestions (*eg.* Fairhurst & Taylor, 1971) the expansion of blanket peat at Lairg is argued to be a result of abandonment, not the cause (Tipping & McCullagh, 1998). Evidence for the maintenance of grazing, even after the settlement was abandoned, also points to the maintenance of claims on the land, even if domestic activities came to be situated elsewhere (*cf.* Nelson, 2000).

The results of palaeoenvironmental investigation in Glen Affric has led to the proposition of another model of settlement for the Bronze Age (Davies,1999). Core-periphery models as proposed for Scotland may see landscapes at as a nested hierarchy of niches at larger spatial scales (Halliday, *unpub*; above and Chapter 1), but Davies (1999)contends that landscapes at any scale should not be viewed as uniformly marginal. Her research in Glen Affric demonstrated that settlement, as reflected in the pollen record, was maintained from the mid-Holocene until the Highland Clearances of the 19th century, in spite of evidence which shows frequent climatic fluctuations (Davies, 1999). The remarkable settlement continuity was explained, firstly as a result of both co-operation between upland farming communities *vis á vis* Fleming's model. And secondly, because farmers were able to recognise and exploit small scale variations in vegetation, it enabled them to selectively exploit and manipulate the most fertile soils, for example alluvial fans, as well as poorer areas of grassland, heath and peatland.

Classifying farms is difficult because soil types, crops, topography, areas of land, natural resources, economic resources (*eg.*, labour pool), skills and opinions will vary from farm to farm (Loomis & Conner, 1992). Historic evidence shows that up until the Clearances, agriculture practices in Scotland were highly localised phenomena (Whyte, 1990). There is of course no reason to assume that any of models above were uniformly in place, which may explain, in part, the continuity of settlement in places as far apart and different in character as Glen Affric (Davies, 1999) and the Borders region (Young & Simmonds, 1995, 2000), whilst settlements at Lairg were abandoned

(McCullagh & Tipping, 1998). The rigid ecological determinations of landscape utilisation and the notion of a prehistoric *Ecce homo* need to be re-evaluated. Contrary to Halliday (1993, *unpub*) prehistoric farmers were not functioning within a market system that we would recognise. Veblenesque models of economy which might apply, arguably, to medieval and later settlement in Scotland, have no demonstrable place in describing the prehistoric economy. In subsistence economies, such as those which appear to be in place in the Bronze Age, social values are a deeply important part of the decision-making process; farmers were not operating on the same system of maximising income and material security that is so familiar to us, but also would have taken into account leisure time, status, ideology and other such 'non-rational' aspects (Bayliss-Smith, 1992).

In societies where dynamic settlement strategies are the norm, attitudes towards land ownership are less likely to be well developed and restrictive; whereas in settled societies the opposite is true (Stone, 1996). In times of stress, sedentary farmers are likely to adopt strategies such as intensification or diversification in production, rather than abandon land in which they have invested a great deal of time, effort and perhaps feel emotionally attached to, as well (Nelson, 2000; Stone, 1996). The continued focus on the over-arching structures by which settlement is determined, that is ecological thresholds, leaves out the very important aspects of everyday life, and how this, too, is a strategy for coping with stress and change (*cf.* Hill, 2001). In the search for large scale patterns of cause and effect, people are left out: monuments are left to 'speak for themselves' (Hill, 2001). Except for the embellished house forms, there is little evidence that traditional hierarchical systems thought to be in place in Europe and southern Britain are apparent in northern Britain (*cf.* Harding, 2000). Social organisation may have been 'heterarchical' through most of the Bronze Age, suggesting less rigid social boundaries where power is unranked, or ranking is contingent and is a continually negotiated process (Crumley, 1995). Not until the building of the brochs is there clearer grounds to suggest the emergence of an elite. Improving the understanding of social organisation, power relations and territoriality is a crucial element in reconstructing the adaptive responses of communities to phenomena such as climate change.

In this 'dots on a map approach' to studying settlement patterns, human agency becomes subsumed in the endeavour to extract patterns from the distribution of monuments and features on the map (Richards, 2001). This, I believe, is clearly evident in the tri-partite model used to characterise hut circle settlements and field systems and the core-periphery model that was constructed from the apparent patterns. Many aspects of the archaeological record which point to co-operation through exchange or other means are ignored, if unintentionally, to the detriment of our understanding of how Bronze Age society in northern Scotland functioned. Alliances and the use of exchange to 'keep up' social relations, which may be evidenced by the widespread distribution of ceramics with steatite inclusions and objects made of shale, have been severely under-rated. During times of plenty, food from one area could be turned into non-food tokens, perhaps a ceramic vessel originating in another area (*cf.* O'Shea, 1983). In times of scarcity, a harvest failure, for instance, the token could be 'redeemed' for food. The regular spacing of hill forts (Figure 3.8) might indicate elements of larger scales of territoriality and control of exchange. Do these represent a gateway between pastoral and arable economies in northern Scotland as argued for elsewhere, or do they serve another more localised role? More importantly, when were they occupied? Was the occupation of hill forts permanent or seasonal?

Chronology remains one of the most intractable problems facing settlement archaeology. Archaeologists from Britain to Central Asia studying subsistence economies have lamented the fact that the smallest unit perceived, the farm, can be extremely difficult to identify on the ground (Fowler, 1978, Thomas, 1983), partly because identifying contemporaneity between different elements of the archaeological landscape is so uncertain. At Lairg the excavators shied away from the use of terms such as 'village' because contemporaneous occupation of different structures was so difficult to demonstrate (Tipping & McCullagh, 1998). At the next level up, identifying simultaneous occupation between farms in different parts of the landscape and demonstrating links is equally fraught with uncertainty (Thomas, 1983). The problem of chronology exists in both attempting to demonstrate the longevity of settlement, as well as brevity or the presence of punctuated abandonment strategies such as transhumance. Archaeological visibility is also an issue. More ephemeral structures which might be associated with temporary dwellings or relating to livestock

management (*eg*, corrals) are not likely to survive their incorporation into the archaeological record in an easily recognisable or recoverable way (Kramer & David, 2001). They may collapse to form mounds, or deflation hollows or be reduced to discolourations in the subsoil. If involved in a transhumance system, they will probably be situated at some distance from main areas of settlements making it more likely that they will be omitted from surveys. How can seasonally occupied dwellings be identified and differentiated? Artefact assemblages might offer some clue (*eg*., Graham, 1996; Nelson, 2000; Stone, 1996), but again demonstrating contemporary occupation between structures adjacent to each other can be difficult, let alone those separated by great distances.

Despite some of the limitations imposed by dating techniques and the nature of the archaeological record itself, the discussion above has shown that the understanding of the settlement in northern Scotland has improved in recent years. Gradually, emphasis is moving away from conceptualising human-environment interactions as linear and proscribed. However, there are still many unanswered questions concerning the nature of subsistence practices, exchange and kinship/alliances. The deployment of well designed investigations with both archaeological and palaeoenvironmental components, *eg*. Lairg, has contributed a great deal to our understanding of settlement and the use of palaeoenvironmental techniques on their own, such as Glen Affric (Davies, 1999) has contributed a great deal to our understanding. Certainly, the continued debate on the degree of sedentariness will be important for some time, and will hopefully produce some new perspectives on how different settlement strategies and social organisation might act in shaping human responses to climate change.

Conclusions

This chapter has demonstrated the complex, multivariate nature of later prehistoric settlement in northern Scotland. Survey data has provided the fundamental basis of our knowledge of later prehistoric settlement, based largely on the morphology and distribution of monuments. The relative lack of excavation means that basic aspects of socio-economic organisation remain unknown. Two primary models of later prehistoric settlement were evaluated. One describes highly (socially) organised, settled farming economies, the other entails a more mobile strategy of shifting

patterns of settlement and agriculture. While not ruling out that a dynamic settlement strategy may have been in place at times, the status of the current model of semi-sedentary farming communities does not address adequately issues of power, territory, exchange, or other aspects of social reproduction. Moreover, it does not follow that either a settled economy or semi-permanent one was necessarily in place, at all locations and at all times. This analysis of later prehistoric settlement and economy in northern Scotland as it is currently understood has, along with the evidence for climate variability in Chapter 2 and the re-evaluation of the theory of Later Bronze Age collapse in Chapter 1, provided a platform for the re-evaluation of putative catastrophes and abandonment of the Strath of Kildonan in the 12th century BC.



Figure 3.1. Remains of a later prehistoric round house or 'hut circle'.

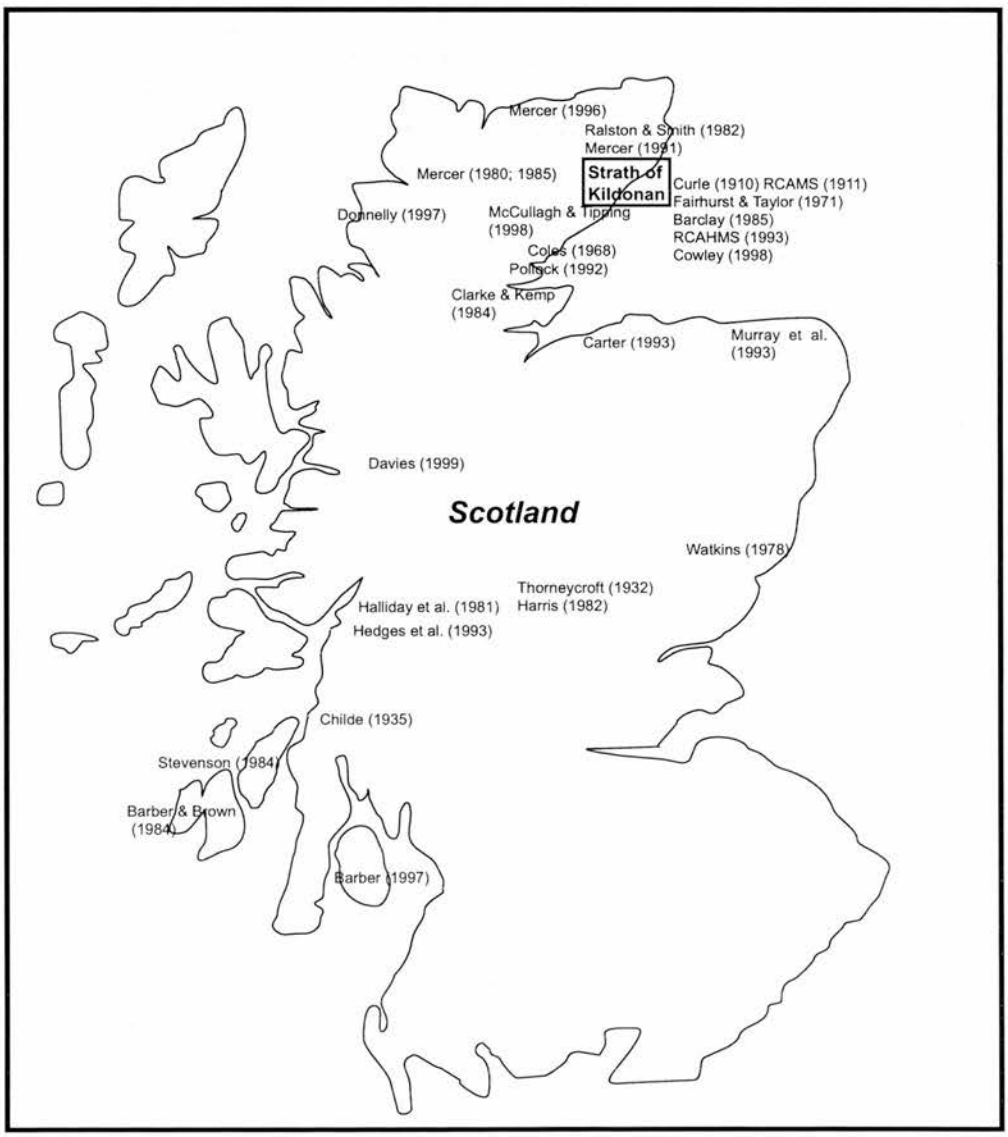


Figure 3.2. Location map of sites discussed in the text.

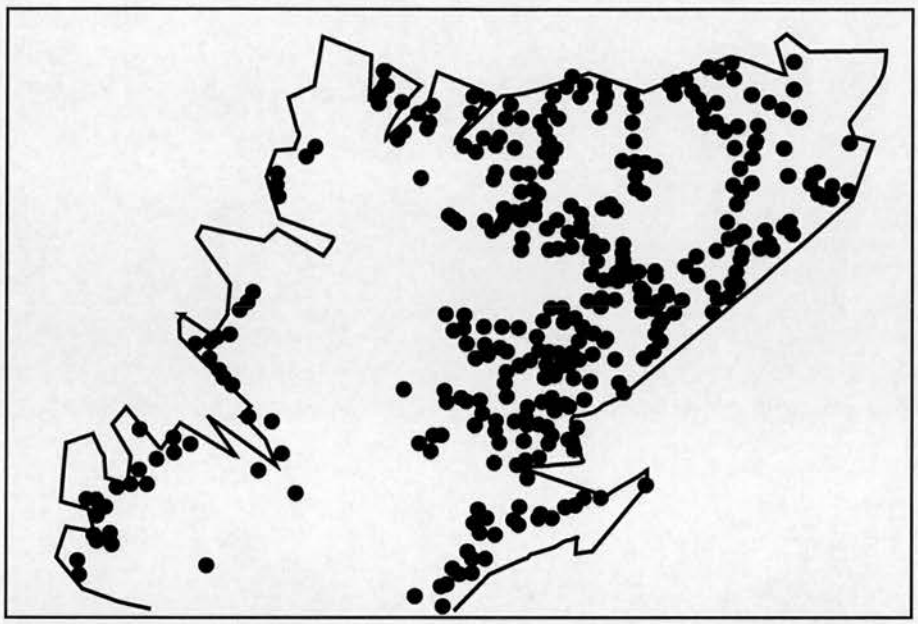


Figure 3.3 Hut circle distribution on the northern Scottish Mainland. This is a generalised view only as markers may represent individual hut circles as well as clusters, Data from RCAHMS © Crown Copyright, 1996.

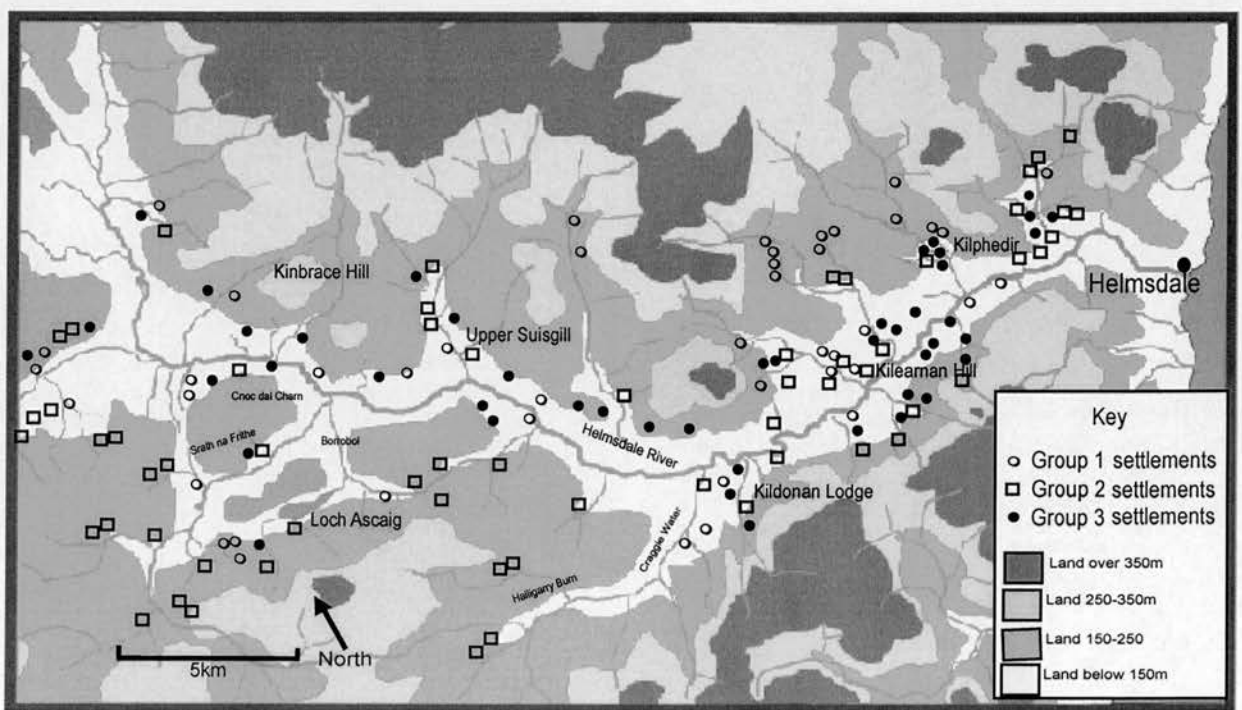


Figure 3.4. Distribution of hut circle settlment types in the Strath of Kildonan

The Strath of Kildonan, Sutherland in northern Scotland. Based on data from RCAHMS, 1992. Crown permission.



Figure 3.5. Burnt mound distribution across the northern Scottish mainland. Data from RCAHMS© Crown Copyright, 1996.



Figure 3.6. Souterrain distribution across the northern Scottish mainland. Data from RCAHMS Crown Copyright, 1996.

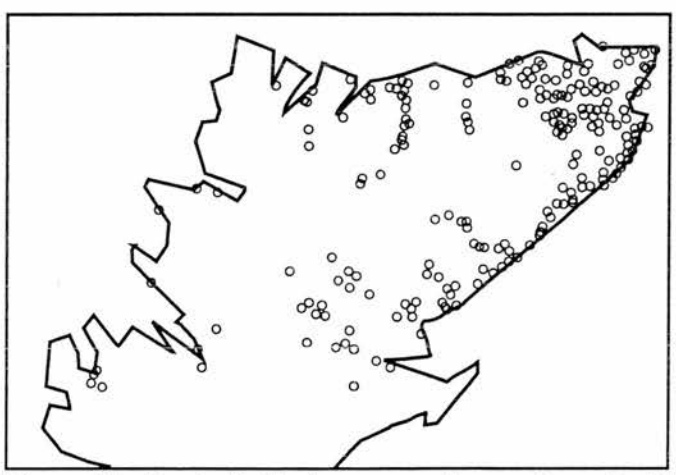


Figure 3.7. Broch distribution across the northern Scottish mainland. Data from RCAHMS © Crown Copyright, 1996.

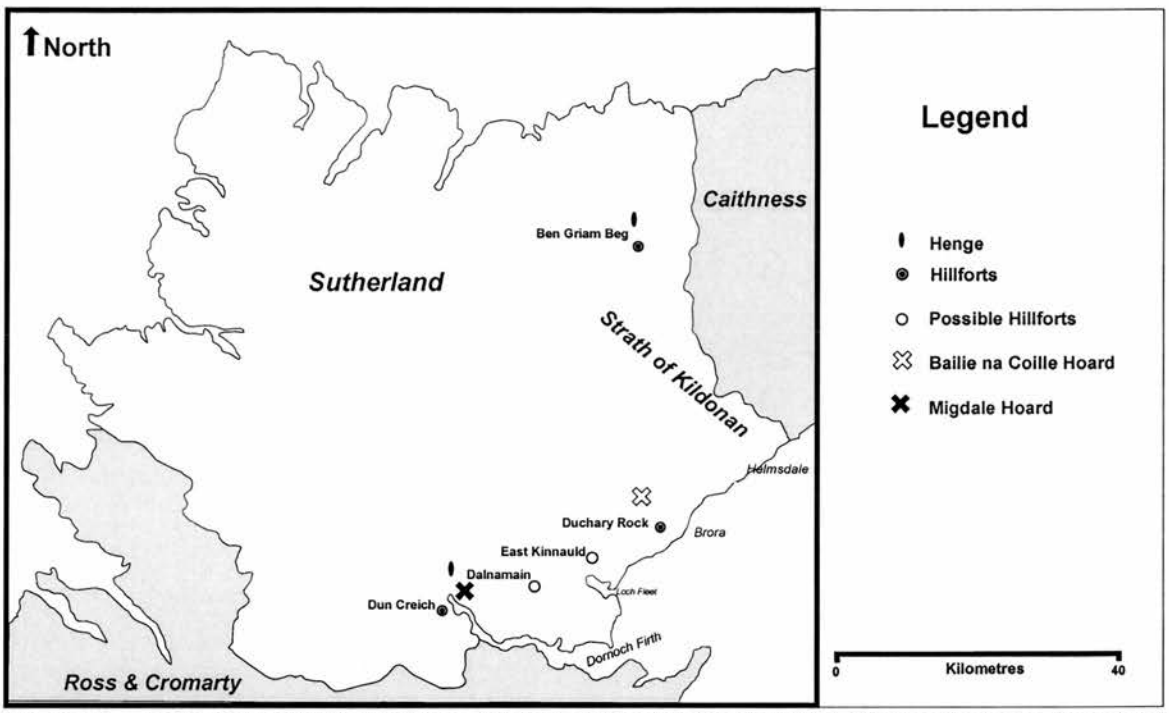


Figure 3.8. Distribution of Neolithic henges, hill forts and hoards in Sutherland The hoards are of different dates, the Migdale hoard is Early Bronze Age and the Baillie na Coille hoard Later Bronze Age. Little is known about the chronology of the henge and hill fort sites. A comparison of this figure with the distribution of metal finds clearly shows that certain parts of the northern landscape played highly visible roles for substantial periods of time.

Data compiled from Coles, 1968, 1969 and NMRS/RCAHMS ©Crown Copyright

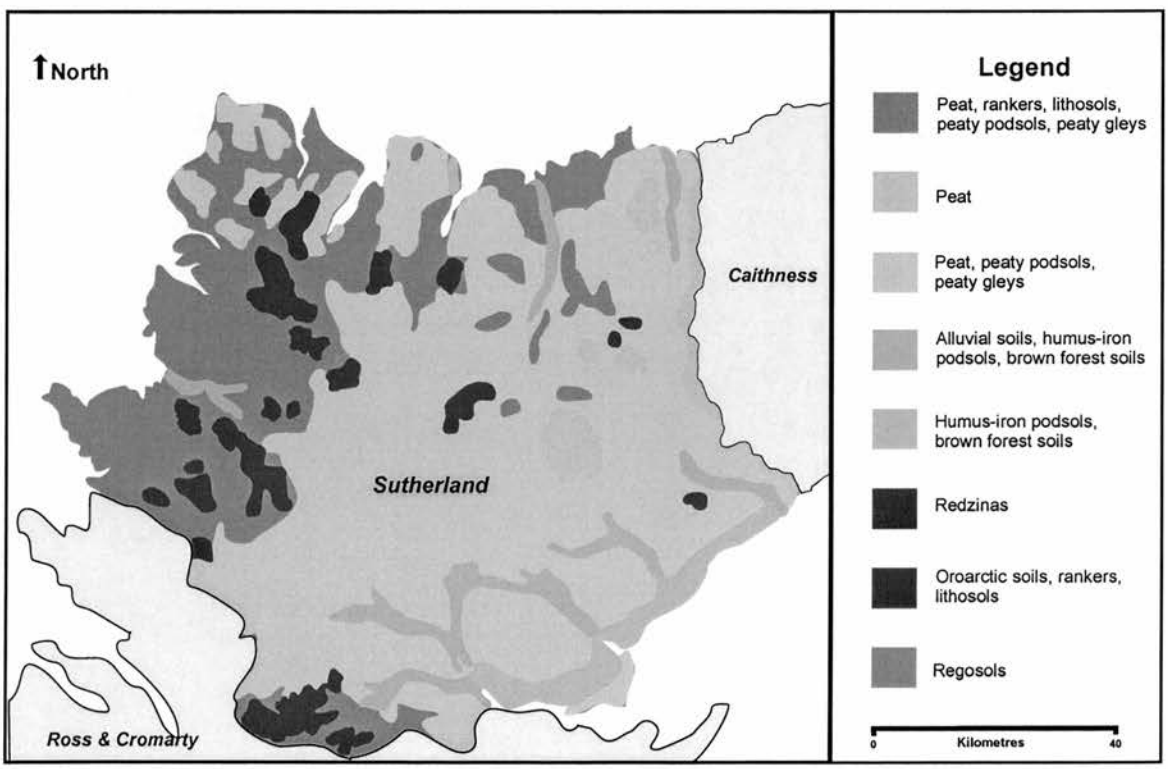


Figure 3.9. Distribution of major soil types in Sutherland.

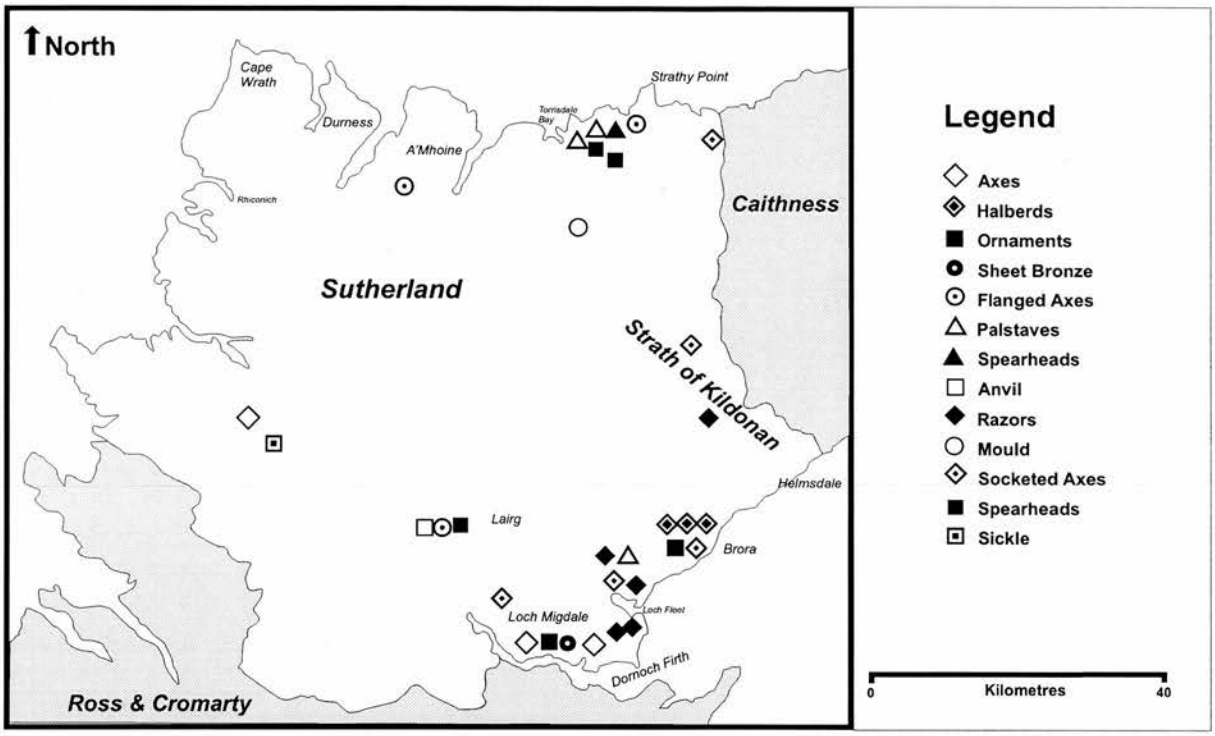


Figure 3.10. Bronze Age metal work in Sutherland. Data complied from Coles, 1968 and Omand, 1981.

Chapter 4

The Strath of Kildonan

> "This parish [Kildonan] lies altogether inland. It may be said to be divided by a great leading strath, into which other less important straths or mountain passes open; and, accordingly the former account of the parish states that 'it resembles a tree, stretching out at the top or the height of the parishes into branches'.
>
> Rev. James Campbell
> *Statistical Account of Scotland* 1841

Introduction

This chapter will analyse and evaluate the evidence used to argue in favour of the 12th century BC abandonment of the Strath of Kildonan. Several palaeoecological reconstructions (Andrews *et al.*, 1985; Birnie, *unpub.*; Charman *et al.*, 1994) have been undertaken in the Strath and these will be evaluated in relation to the archaeological data and in the context of regional vegetation change. Ideas of population crises, marginality and settlement abandonment will be re-evaluated in the context of archaeological data from survey and excavation. The prehistoric and later archaeological landscape of the Strath of Kildonan is characterised by extensive remains of chambered tombs, field systems, hut circles, burnt mounds, and brochs (Figures 4.1-4.4). Structures and features representing prehistoric activity from the Neolithic onwards are best preserved on the valley sides. Evidence for prehistoric settlement is rarer closer to and on the valley floor; centuries of land use as well as fluvial and erosion activity may have eradicated evidence of more extensive occupation of these areas (Barclay, 1985; RCAHMS, 1993). In other areas of the Strath, preservation of monuments varies considerably, depending on such factors as the nature and intensity of later activities or peat growth (Barber & Lowe, 1988). The tripartite scheme of hut circle settlements and field systems formulated in relation to survey data (Cowley, 1998; RCAHMS, 1993; Figure 4.2) has already been introduced and discussed in Chapter 3 because of its importance to models of later prehistoric settlement as whole.

The Archaeological Landscape of the Strath of Kildonan

Some early investigations

Investigations into hut circles by A.O. Curle (1910; RCAMS, 1911) early in the 20th century led him to suggest that they were in use from the Bronze Age until the 19th century. Curle was disappointed to find very few artefacts during the excavation of two hut circles, one on Kinbrace Hill (NC 861 2963) (Figure 4.5) and the other near Loch Ascaig (Figure 4.5). The Loch Ascaig hut (NC 8325 2562) consists of two stone banks 1.5m apart, joined by an entrance passage. The outer circle is constructed of compacted earth and stone, and the inner circle of rubble, and is roughly faced. A hearth was found in the centre of the hut. Although Curle (1910) originally believed that this structure was constructed with double walls, subsequent re-survey indicates it probably represents two separate phases, with a later, smaller house inserted into the earlier, larger one (RCAHMS, 1993). Traces of a small rectilinear structure were found near the entrance, function unknown. A saddle quern was also found. During his excavation of a hut circle and souterrain on Kinbrace Hill, Curle (1910) recovered a fragment of a lignite armlet, possibly D-shaped in cross section; ornaments of this type have been associated with Later Bronze Age horizons at settlements elsewhere in Britain (Annable & Simpson, 1968).

Kilphedir

As was noted above, the Kilphedir excavation (Fairhurst & Taylor, 1971; Figure 4.5) served as a model for later prehistoric settlement archaeology throughout Scotland, with a great deal of emphasis placed on the results of the radiocarbon dating programme. The settlement of five huts is located at 80m OD (NC91 NE25), situated in an area of ground smoother than the surrounding moorland, and interpreted as the 'arable area' and estimated at about 2ha. There are several clearance cairns and stone banks, but nothing which directly supports animal husbandry, at least on an extensive scale. The settlement appears to span two phases. Houses I-IV were described as Curle's 'Type I' (RCAMS, 1911) settlements comprising simple hut circles with some clearance mounds. The houses were covered with a thin layer of peat which it was suggested began forming sometime between 2,300-400 BP. A subsequent radiocarbon determination from wood charcoal samples from directly beneath the peat

was 2370 BP which the authors suggested was equivalent to 400-450 BC in calendar years (Table 4.2)

Hut V was described as "massive in construction" and likened to the galleried duns of western Scotland. (Fairhurst & Taylor, 1971.). It was compared to Curle's Type 2 (RCAMS, 1911), larger more solidly built structures whose foundations may be faced with slabs, have elongated entranceways and sometimes be found with souterrains. Two distinct phases of occupation are apparent at Hut V; it was the second phase which resulted in the build up of the massive walls and produced the club-like thickening of the entrance terminals. The second phase of Hut V occupation ended with a conflagration and was dated to around 150 BC (Table 4.2)

Like most excavation of hut circles, Kilphedir yielded very few artefacts. The flat-rimmed pottery recovered from the Type 1 settlement is characteristic of Later Bronze Age ceramics in northern Scotland. The coarse, flat rim types found have parallels with ceramics known from the excavations of brochs at Keiss, Caithness (Anderson, 1901). Pottery found in later occupation contexts at Lairg, some 40km away, had steatite inclusions (Chapter 3). Ceramic finds from the Type 2 settlement (Hut V) were finer; rims were everted rather than flat. The only other notable finds were a saddle quern in Hut V, a few pounders and a stone disc.

Context	Description	^{14}C Age Estimation	Calibrated Ages
Occupation	Charcoal from sealed beneath peat layer covering site	2370±40 (GU-299)	540-380 BC 2490-2330 BP
Abandonment	Charcoal from post-abandonment deposit	1992±60 (GU-10)	125-130 BC 2075-1820 BP
Abandonment	" "	2064±55 (GU-11)	200 BC- AD 60 2150-1890 BP
Abandonment	" "	1978±60 (GU-67)	120 BC- AD 140 2070-1815 BP
Abandonment	" "	2100±80 (L-1061)	265 BC-AD 60 2215-1895 BP
Abandonment	" "	2100±50 (SRR-3)	210 BC-AD 10 2160-1940 BP

Table 4.2 Radiocarbon determinations and contexts from Kilphedir (Fairhurst & Taylor, 1971)*.

* All dates have been calibrated from the original published ^{14}C determinations using the programme CALIB 4.1.2 (Stuiver & Reimer, 1997).

Something that seems to be commonly overlooked, is that Fairhurst & Taylor (1971; also Fairhurst, 1971) argued that occupants of the Type 1 settlements were descendants of the previous Neolithic and Bronze Age peoples who had colonised the Strath. The Kilphedir settlements provide a link between Bronze Age and Iron Age settlement with no suggestion of a hiatus. Foreshadowing later developments (Chapter 3), Fairhurst wondered if perhaps the houses of the Bronze Age people were "... being overlooked or confused with those of later settlement" (1971:8). The abandonment of the Type 1 houses occurred *ca.* 400 BC, conveniently on the sub-Boreal to sub-Atlantic transition, and it was suggested their abandonment might have been related to worsening climate conditions. By the time House V was destroyed, peat growth, it was suggested, would have spread down hill, threatening the Type 2 settlement.

The significance of Kilphedir was re-assessed by Mercer (1985, 1996). He argues that the radiocarbon results from Kilphedir offer little more than *terminus ante quems* for the occupation of the settlement; they do not provide information concerning the construction or occupation of the structures, especially concerning the first phase of House V, which may have been substantially earlier than phase 2 when the house was destroyed by fire. The finds of both flat-rimmed and everted pottery also point to, he argues, a continuity from the Later Bronze Age through the Iron Age in terms of the occupation of the settlement itself, not simply a horizon of Iron Age occupation.

Upper Suisgill

The Upper Suisgill settlement is located at *ca.* 100m OD (NC 897 251) approximately 10km inland from Kilphedir (Figure 4.5). The site was revealed after the catastrophic failure of the road and during subsequent re-surveying (Barclay, 1985) and presented a surprise to expectations about typical later prehistoric settlement in northern Scotland. The earliest activity revealed by excavation was a set of ard and spade marks (Period I; Table 4.2). Sometime after cultivation had ceased a timber round house (House 1a) was constructed on the site (Period II). A second house (House 1b) was later reconstructed over the first. During Period II an earthen bank which appears to have been crowned with a two parallel lines of stakes was also constructed. Period III saw cultivation resumed over the site of the house[s] and the bank, severely damaging features and scattering materials.

Charcoal from two post-holes was obtained for radiocarbon age determinations (GU-1492 and GU-1490; Table 4.3), although it was noted that the arrangement of post-holes formed no coherent shape, and in many cases subsequent post-holes re-cut earlier ones. Period IV was characterised by the construction of House 2, which was apparent only as four stone-packed post-holes. The house was burnt down and ploughed over, scattering and badly disturbing most of the material thought to be associated with Period IV occupation/destruction. Charcoal from one of the posts was submitted for dating, GU-1490, but it will be noticed that GU-1490 (Table 4.3) was apparently also taken from a post-hole in House 1b, in Period II. Another sample was submitted from burnt material taken from on top of the earthen bank, GU-1493 (Table 4.3) thought to be related to the burnt post material of the structure.

Period V describes the ploughing over of the destroyed structure and bank. Another wall was built following the line of the original bank, possibly delineating a small cultivation plot. Later, Period V was marked by severe erosion; occupation deposits were washed away and thick gravel layers deposited over the site. It does not appear to have been a single event, and there was thought to be evidence for human activity (unspecified) in the gravel layers themselves. Water-logged wood fragments obtained from the gravel were submitted for dating (GU-1326; Table 4.3). During Period VI, use of the site was re-established on top of the gravel, overlapping with construction at least one of the souterrains. Primary evidence for activity are a series of stake and post built fences. The site was again inundated and gravel deposited. A final age estimation was submitted from Period VI, its context given as an occupation layer, although the nature of this is not clear. Consequently it was argued that the Suisgill site represented occupation from the early- to mid-first millennium through the late first millennium BC, with perhaps some intermittent occupation at an unspecified later date.

Period	Description	^{14}C Age Estimation and Context	Calibrated Ages
I	Tillage preserved under earthen bank	—	
II	Construction of timber building, earthen bank; reconstruction of timber building	2775±105 BP (GU-1492): Charcoal from post-hole of House 1a.	1220-785 BC 3170-2735 BP
III	Tillage resumed; house site ploughed over.	—	
IV	A post-built structure is built over period II house and was later burnt.	2940±60 BP (GU-1493): Burnt stakes on top of primary settlement bank. Part of House 2? 2835±90 BP (GU-1490): Burnt post of structure 2.	1315-980 BC 3265-2925 BP 1230-820 BC 3180-2770 BP
V	Ard cultivation and further tillage; erosion: some parts of occupation deposits washed away, layer of gravel deposited over substantial area of site.	2580±60 BP (GU-1326): Twigs and small branches preserved in colluvium.	840-510 BC 2790-2460 BP
VI	Settlement re-established on top of colluvium. Stake and post built structures; second phase of colluviation Construction of souterrian?	2205±65 BP (GU-1491): Charcoal from occupation layer.	395-105 BC 2340-2055 BP
VII	Traces of occupation deposits in upper levels of colluvium	—	
VIII	Recent occupation and road construction.	—	

Table 4.3 Periods of settlement, radiocarbon determinations and contexts from Upper Suisgill (Barclay, 1985)

The construction of several walls and banks out of earth and stone and indications of stake built structures revealed a complex system of intra-site land divisions (Barclay, 1985). The exact functions of these various features were not discernible from the fragmentary remains recovered through excavation. However, it was speculated that the substantial earthen banks may have served some role in livestock management. Despite the traces of ard and spade cultivation at various times, only fully processed cereal crops were recovered (van der Veen *in* Barclay, 1985). Saddle querns and a rotary quern, all recovered from disturbed contexts, indicate that the later stages of crop processing were practiced on site. Some water-logged plant remains were recovered of weeds normally found in arable or ruderal situations, but some of which, *eg.*, *Chenopodium album* and *Spergula arvensis*, are used as food in their own right. *Corlyus* shell fragments indicate that hazel nuts were also collected. This contrasting physical evidence of cultivation with a lack of crop processing residue has parallels with Lairg (Tipping & McCullagh, 1998). At Upper Suisgill, as at Lairg, it remains unclear what crops were grown and whether or not cereal was cultivated on a small scale or 'imported'.

Quantities of pottery sherds and fragments of shale bracelets were recovered (Lee & Barclay, 1985). Some, but not all, fragments of pottery had steatite inclusions and the assemblage included a gradual transition from flat to everted rim forms. Repeated episodes of tillage, occupation and colluviation, often superimposed on each other caused considerable damage to features and artefacts. For example, sherds from the same vessel were discovered in both period I and period V contexts. All of the pottery was not included in the final report, on the grounds that it was "uninformative" (Lee & Barclay *in* Barclay, 1985:183), but at least one fragment in the published catalogue showed signs of abrading, and this could be related to the past episodes of flooding and erosion. Of the three fragments of shale bracelet recovered, only one had an intact cross section, but this was not described, and all were recovered from later or disturbed contexts. Although no petrologic analyses were performed, possible relationships to the Jurassic outcrop near Brora were suggested (Collins *in* Barclay, 1985)(Chapter 3). Sandstones recovered matched Middle Old Red Sandstone from Caithness.

The excavation was also accompanied by a programme of palaeoenvironmental reconstruction (Andrews *et al.*, 1985). Two cores were sampled from an area of blanket bog at 183m OD on Cnoc Bad na h-Eirig, 2km from the Upper Suisgill site (Figure 4.5). Peat began forming there *ca.* 7620-7430 cal BP (5670-5480 cal BC) and the vegetation fluctuated between open *Pinus-Betula* woodland and open heather moorland/acid bog. A notable reduction in woodland took place just prior to *ca.* 5320-4825 cal BP (3370-2880 cal BC), accompanied by the expansion of open, disturbed habitats, interpreted as anthropogenic in origin, and bog. It is suggested that woodland decline and inferred expansion of blanket bog may have been a combination of Neolithic clearances and climate change. Forest regeneration is not recorded until *ca.* 3,650-3,455 cal BP (1700-1505 cal BC). The open *Betula-Pinus* woodland remained largely intact until a second phase of minor disturbance *ca.* 2,790-2,460 cal BP (840-510 cal BC) The rise in *Alnus* and *Sphagnum* around this time are linked to climatic wetness and the water-scouring and erosion apparent at the Suisgill site. From *ca.* 1825-1420 cal BP (cal AD 125-530), woodland underwent a sustained reduction and is associated with the expansion of pastoral activities. Smaller scales of

woodland regeneration in the upper part of the core are linked to the Highland Clearances of the later 18th and early 19th centuries. The vegetation history offers some corroborative information to the excavation, but the low sampling resolution (10cm) and distance from the site obscures any short term human impacts or other vegetation change (*cf.* Tipping, 1994), as well as smaller incursions taking place closer to the site.

Disappointingly, little detailed attention was given, at least in the published report, to the dynamic processes, both anthropogenic and 'natural', which influenced the formation of the Upper Suisgill site. In terms of the frequent flooding and erosion, however, one plausible scenario was put forward. Water and gravel appeared to have followed a channel down a hill slope to the east of the site. The stratigraphy of the gravel layers suggested several minor events, punctuated by two larger ones, lasting perhaps several decades. It was suggested that gullying, caused by animals be moved up to the plateau for grazing, might have developed into a watercourse during heavy rainfall. The superficial approach taken to site formation processes, at a site so obviously disturbed by ploughing and flooding, and the lack of a critical dating strategy throws the accepted chronology of Upper Suisgill severely into doubt.

Armit (1991) re-examined the chronology of Iron Age settlement in Scotland. In his analysis, he excluded all but one of the age estimations from the Upper Suisgill excavation because the absence of clear relationships between the radiocarbon age and structural units (Figure 4.3). I would also exclude GU-1491, because the published report does not make the occupation layer clear. Period VI is comprised of gravel inundation, pit construction and souterrains, it is not clear what aspect of Period VI GU-1491 is 'dating': the souterrains or the pits dug into the gravel? Subsequently, the excavation has added little to the knowledge of later prehistoric occupation histories and chronology. In terms of pottery, Mercer's (1985; 1996) argument that the transition from flat rimmed to everted rim forms represents a Later Bronze Age to earlier Iron Age time span might apply, suggesting an earlier range of occupation at Upper Suisgill.

Kilearnan Hill

The Kilearnan Hill settlement is located roughly 3km to the west of Kilphedir, but on the south bank of the Helmsdale River (Figure 4.5) The areas investigated included nine hut circles with field plots/clearance cairns, two burnt mounds and a broch, all scattered between the 31m OD and 213m OD (McIntyre, 1998). The earliest human activity at the site was associated with a clearance heap, excavation of which produced a Beaker fragment. A sample from the basal soil provided a *terminus post quem* of *ca* 1950-1400 cal BC (Table 4.4). Four of the nine huts were selected for excavation as well as one of the burnt mounds. Hut 1 appears to resemble Mercer's (1985) type 6: it is described as more of a 'platform' than a substantially built structure, occupied by a simple circle of stones (McIntyre *et al.*, 1998). The walls are comparatively thin, never exceeding 1.4m. After the discovery of the timber built structure at Upper Suisgill, it has been suggested that huts elsewhere in the Strath of Kildonan were timber built, with the low stone walls reflecting the clearance of field stones heaped against the timber walls (RCAHMS, 1993). However, in Hut 1 at Kilearnan Hill, only two features which could be reliably identified as post-hole were found, and only one of these revealed stone packing.

No hearth was found, but the presence of lithic fragments, which were thought to indicate on-site tool production, and pottery sherds led the excavator to interpret this structure as a dwelling. A sample for radiocarbon dating (GU-1920; Table 4.4) was obtained from one of the several silt and charcoal lenses which had built up along one wall of the structure. These were suspected to be the product of erosion of sediments into the structure. In fact, evidence of erosion was extensive across the site as a whole. The age estimation of 1490-1950 cal AD was considered non-contemporaneous with the occupation of the structure. These same erosion layers appear to be in the context of some of the lithics and pottery recovered. There is no indication as to whether or not the materials were abraded or otherwise by erosion or how this might potentially affect their relationship with Hut 1.

Hut 2 is the only structure that reflects the types of architectural embellishments seen, for example in Hut V from Kilphedir (Fairhurst & Taylor, 1971) or House 4 at Lairg (Dalland & McCullagh, 1998). The walls of Hut 2 exhibit a considerable thickening at the entrance, along with an internal cell, features commonly associated with huts in

Group 3 settlements (RCAHMS, 1993). A central hearth is only tentatively inferred from a spread of charcoal in the centre of the structure. A radiocarbon sample from the charcoal produced an age range of 1380-930 cal BC (GU-1919). The only artefacts recovered were a few lithics identified in an erosion deposit. Huts 3 and 4 were both badly damaged by earlier forestry ploughing, but both appear to have been of simple construction, perhaps similar to Type 1 houses. Scattered lithics and pottery with steatite inclusions were recovered from Hut 3; another pot sherd with talc inclusions was discovered just outside Hut 4. A sample for radiocarbon dating was obtained from what was defined as a post-abandonment context in Hut 3, a charcoal layer sealing post-holes in Hut 3, returning an age of 1050-400 cal BC (GU-1917). A sample from a putative occupation layer from Hut 4 gave an age range of 220-620 cal AD (GU-1918). Huts 2 and 3 both had paved entrance ways; features which have parallels in Hut V at Kilphedir (Fairhurst & Taylor, 1971) and a hut circle excavated at Rhiconich, on the NW coast of Sutherland (Donnelly, 1997).

Pottery sherds associated with Hut 1 did not have steatite inclusions and reflected more everted rims and globular forms, similar to pottery which was associated with later periods of occupation at Upper Suisgill (MacSween *in* McIntyre, 1998). The steatite tempered pottery from Huts 3 and 4 was flat rimmed. Similar pottery from Lairg dated to much earlier contexts, 1800-1200 BC (Dixon & Macsween, 1998), than Upper Suisgill which appears to agree better with 1050-400 cal BC age from Kilearnan Hill (MacSween *in* McIntyre, 1998). However, it was noted that too little information is available to rely on the presence or absence of steatite inclusions as a chronological indicator. Based on comparisons with the Upper Suisgill material is was suggested that the ceramic evidence from Huts 3 and 4 dated from the early to first millennium BC and that from Hut 1 to the later first millennium. It was tentatively suggested since deposits outside Hut 4 (AD 220-620) produced earlier talc tempered pottery, this apparent late occupation may reflect re-use (rather than primary occupation) and that the outside deposit with the ceramics is cleaned out floor material.

Context	Description	^{14}C Age Estimation	Calibrated Ages
Hut 1 (abandonment?)	Charcoal rich floor deposit	250±55 (GU-1920)	AD 1490-1950 285-175 BC
Hut 2 (abandonment?)	Charcoal rich soil from hearth area	2935±65 (GU-1919)	1380-930 BC 3265-2920 BP
Hut 3 (post abandonment?)	Charcoal in interior soil layer; possibly eroded.	2645±100 (GU-1917)	1050-400 BC
Hut 4 (putative occupation layer)	Charcoal from interior sediment, possibly eroded	1640±85 (GU-1918)	AD 220-620
Cairn 12	Charcoal rich soil layer in cairn	3380±105 (GU-1916)	1950-1400 BC 3870-3385 BP
Burnt Mound	Charcoal from phase 2	2815±60 (GU-1914)	1150-830 BC 3080-2780 BP
Burnt Mound	Charcoal from dumped phase 2 material	2820±95 (GU-1921)	1260-810 BC
Burnt Mound	Charcoal from basal layer phase 3 material	2660±95 (GU-1912)	1050-400 BC 2990-2460 cal BP
Burnt Mound	Charcoal from dumped phase 3 material	2750±80 (GU-1913)	1130-790 BC
Hearth overlying burnt mound	Charcoal from hearth deposit	510±60 (GU-1915)	AD 1300-1490 650-465 BP

Table 4.4 Radiocarbon determinations from Kilearnan Hill (McIntyre, 1998).

Hut 1 might arguably be shown to be a workshop or byre, in the absence of evidence for a hearth, an essential feature of dwellings (*cf.* O'Sullivan, 1998). Detailed soil analysis, such as phosphate content, of living floors might be one approach to shedding more light on the use of Hut 1, which of course may have altered through time. For at least two of the houses, Hut1 and Hut 4 chronological information is questionable considering the uncertainty associated with the material and contexts dated. The age estimations from Huts 2 and 3 seem to provide more reliable *terminus post quems* for hut circle occupation, if little information is apparent about the longevity or other aspects of their occupation histories. Interestingly, age estimations from the several phases of burnt mound use appear to overlap to some extent with occupation of the huts, as well as indicating, broadly, use in the 12th century BC *contra* earlier assertions by Barber (1990). The chronology of the ceramic sequence was closely tied to that of Upper Suisgill, but given the chronological problems with that site discussed above, there are reservations on the reliability of this.

A pollen core was investigated in conjunction with the investigation (Birnie, *unpub*). The core, 1.15m in depth was obtained from a section of deep peat adjacent to the Oulmsdale Burn (Figure 4.5) and located approximately 300m E of a group of cairns, 300m N of one the burnt mounds and about 0.5km from the nearest hut circle. A

basal date showed that the peat began accumulating in this area *ca.* 3,465-2,845 cal BP (1515-900 cal BC). Tree pollen percentages are generally quite high, 70-80%, and are sustained until just before cal AD 1260-1420, with only a few minor incursions. The woodland was dominated by *Alnus* and *Betula*, sometimes alternately. Both *Betula* and *Alnus* are high pollen producers, which may help explain the elevated percentages of tree pollen, considered unusual in northern Scotland. Wood macrofossils in the sediment indicate that trees were growing locally at times.

The lower tree pollen percentages apparent between *ca* 3,465-2,845 and 3,070-2,780 cal BP suggests some clearance; human activity is most evidence during this period, marked by pollen of both pastoral and arable indicator species. After 3,070-2,780 cal BP (1120-830 cal BC), indicator taxa became less common and cereal pollen more sporadic, thought to reflect a reduction in activity or the shift in focus elsewhere in the catchment. The next major phase of activity recorded near the burn is the expansion of heathland, which it is thought may have been encouraged by burning, and was accompanied by the disappearance of woodland. This vegetation change took place sometime after cal AD 1260-1420. Increasing water-logging of the site is suggested from the Later Holocene, but no explicit links were made with evidence for climatic change in either the pollen report or excavation report.

The excavation report argues for abandonment of hut circles upslope *ie.*, Huts 1 and 2 from 3070-2780 cal BP, due to peat encroachment (McIntyre, 1998). By the time the peat began to accumulate along the Oulmsdale Burn, Kilearnan Hill was "... a settled farming economy whose days were numbered by increasing acidification of the soils and the onset of blanket peat formation." (McIntyre, 1998:200). The large separation between the dates of Huts 2 and 3, broadly contemporary with the onset of peat accumulation along the burn, and Hut 4 which is much later, *ca.* 220-620 AD, appear, it seems, to indicate a hiatus. It is argued that the encroaching peat would have led to pressure on the land and may have resulted in the construction of the broch along Gylable Burn, which seems to imply its construction as a defensive structure. Again, analogies are drawn with the Kilphedir excavations to 'explain' the occupation and disuse of the Kilearnan Hill settlement.

There is some disagreement apparent between the published excavation report and the pollen report, which suggests that some activity may have continued in the catchment after 3070-2780 cal BP, but not adjacent to the pollen site. To this could be added that the pollen record may be recording primarily local vegetation after 3070-2780 cal BP. *Alnus* is likely to have colonised the stream bank, given its preference for wet soils with high water tables (Savill, 1991). The high pollen productivity of both *Alnus* (*cf.* Janssen, 1959) and *Betula* combined may have effectively masked any activity not taking place in the immediate area or small scale incursions (*cf.* Edwards, 1979, 1981; Edwards & McIntosh, 1988). The patchy chronology of the structures and their occupation histories, coupled with the fact that less than half of the houses were excavated increases doubts about the wholesale abandonment of the site during the Later Bronze Age, especially since there seems to be an implicit desire to shoehorn the excavation results in the generally accepted chronology of northern round house settlement.

The final report raises more questions than it satisfactorily answers concerning the occupation history for the four structures and post-abandonment site formation processes. It seems clear that erosion was an important factor in the accumulation of sediments both in and around the huts; the potential impact on the record of occupation and artefact distribution/recovery, as well radiocarbon dating source material, was not adequately addressed. It was indicated that none of the dates and only a few of the finds could be assigned to primary contexts with any degree of confidence. Reference date material was not identified beyond 'charcoal' and target dates were unclear, generally because the contexts were poorly defined. For example, the dated occupation layer in Hut 4 was accompanied by a question mark, and consequently does not, as the report implies, provide a 'date' for the construction of Hut 4. As with Kilphedir, the age estimations from Kilearnan Hill only offer the most tentative *terminus ante quems*

Craggie Water

The Central Excavations Unit's (1988) pre-afforestation survey of the Craggie Water catchment (Figure 4.5) was accompanied by the limited excavation and survey of a cairn field near what is the Kildonan Lodge site in this study (Russell-White, 1998). The field is situated on the west bank of the Allt na h-Airbhe (NC 906 184). It was

hypothesised that this field system reflected Neolithic and/or Bronze Age activity. It was speculated that the apparent lack of settlement might be because associated structures may have been timber built, as at Upper Suisgill (Barclay, 1985). Several alleged man-made features were noted during test pit sampling, including a hearth and post-holes. Charcoal was abundant in some pits, while others reflected very high phosphate values. Samples for radiocarbon dating were obtained from underneath two clearance cairns about 40m apart. The first provided a *terminus post quem* of 780-400 cal BC and the second cal AD 530-970 (Table 4.5). Beside the clearance cairns, the only clear cut man-made features were two furrows *ca.* 1-1.5 m wide, running east to west across the cairnfield and a series of ard marks under 50.0 cm of peat. A radiocarbon sample from the basal layer of peat returned an age of cal AD 870-1040 (Table 4.5). The furrows had been cut into the soil and subsequently filled with peat, and possibly represent a late period of cultivation and/or drainage.

Period	Description	^{14}C Age Estimation	Calibrated Ages
1	TPQ for construction of a cairn in area D2.	2450±80 BP (GU-2951): Soil beneath cairn	780-400 BC 2730-2350 BP
2	TPQ for construction of a cairn in area F2.	1420±60 BP (GU-2950): Layer of peat beneath cairn.	AD 530-720 1420-1230 BP
3	TAQ for ard marks in areas B2	1070±50 (GU-2949): Basal layer of peat above ard marks.	AD 870-1040 1080-910 BP

Table 4.5 Radiocarbon determinations for Allt na h-Airbhe (Russell-White, 1998).

It was concluded that there was no clear evidence for pre-Iron Age settlement in the area Based on the radiocarbon dating programme, it was argued that agricultural activities in this part of the Craggie Water catchment were limited to two phases, the first in the early Iron Age and a later Dark Age phase. It was noted that the earliest phase of occupation overlapped with Period V at Upper Suisgill (Barclay, 1985) and the occupation of Hut 3 at Kilearnan Hill (McIntyre, 1998). The radiocarbon dates provide evidence that the cairnfield of Allt na h-Airbhe "...fits comfortably into the known archaeological and chronological framework for the central area of the Strath of Kildonan." (Russell-White, 1998:34).

An excavation of a hut circle in this catchment remains unpublished (Lowe, *unpub*), but a radiocarbon age estimation of 3200±50 BP (1543-1386 cal BC) was quoted in a

recent publication by Cowley (1998). The context of the sample is not clear from the secondary source, although it is implied that it was obtained from a primary occupation context, originating in a section through the hut circle bank. The source material is not referred to.

Prehistoric "Highland Clearances"?

The principle set of data used to infer the abandonment of the Strath is the lack of radiocarbon dates after 1000 uncal BC [ca. 1200 cal BC] (Barber, 1997) (Figures 4.6.& 4.7) Taking a cue from Burgess (1989), Barber (1990; 1997) suggested that 'nuclear winter' conditions, caused by the eruption of Hekla in 1159 as dated by Baillie (1989) resulted in the abandonment of the Strath. Barber (1997) calls for a climate deterioration beginning 1300-900 cal BC with an 'unprecedented' period of wetness between 800 and 400 BC. The regional soil deterioration from the late second millennium BC (Fairhurst & Taylor, 1971; Romans & Robertson, 1975) would have intensified with the deteriorating climate conditions. Further exacerbating the situation was the eruption of Hekla 3 in 1159 BC (Baillie, 1989), which would have resulted in 'nuclear winter' conditions (Barber, 1997). On the grounds that there were no dated 12th century BC settlements (Barber, 1997), Grattan & Gilbertson (1994) incorporated the Strath of Kildonan into their argument that prehistoric eruptions of Icelandic volcanoes would have polluted the 'marginal' soils of upland Britain, killing off both vegetation and animals.

Barber's use of calibrated and uncalibrated 'dates' is misleading, however. Calibrated age ranges in Figure 4.8 indicate a far higher likelihood that dated occupation horizons and other features fall somewhere within the range of the supposed hiatus. The absolute number of radiocarbon 'dates' is a little misleading as well. As already noted, the Kilphedir chronology has been used as the basis for the chronology of hut circle occupation for some time (Chapter 3). However, it should be noted that all but one age estimation come from the same post-abandonment context of a single house on the site, out of the five investigated (Table 4.1). A further problem is the radiocarbon plateau between 800 and 400 BC, but Barber (1997) gets around this by arguing that it is the absolute number of dates which fall into the latter part of the period between 1200 and 400 BC.

Applying the same approach used by Armit (1991) to the Kilearnan Hill data, at least two more age estimations can be excluded (Figure 4.9) because the contexts of these dates are not clear. At Kilearnan Hill, as at Lairg, more reliable radiocarbon evidence suggests that burnt mound use was related to hut circle settlements. Furthermore, *contra* previous beliefs by Barber (1990, 1997) there appear to be three phases of burnt mound use during the late second millennium through the early first millennium BC. The radiocarbon age estimations for the hut excavated at Craggie Water have been excluded as well (Lowe, *unpub.*in Cowley, 1998); the site is unpublished and no definite contextual information is available. The Kilphedir data have been excluded because none them seem to be reliably associated with the occupation contexts of the hut (*contra* Armit, 1991). This age estimation was obtained from charcoal derived directly beneath the peat layer (Fairhurst & Taylor, 1971), and therefore, more accurately describes the abandonment of the structure rather than any periods of occupation. As a result of this exercise, it can be seen that the chronology of settlement in the Strath of Kildonan has not been constructed on reliable data.

The chronology and occupation histories of the excavated and surveyed structures are poorly understood. In most cases, it is not clear when the structures were built and in several cases, it is not clear when they might have been abandoned. The principle deficiencies are related to sample provenience factors (Taylor, 1987), and with respect to the earlier work undertaken in the Strath of Kildonan, the use of uncalibrated dates, or a mixture of calibrated and uncalibrated, to construct chronologies. Flat and everted rim pottery recovered from all of the round house excavations in the Strath may indicate Later Bronze Age-Iron Age continuity of settlement (*sensu* Fairhurst & Taylor, 1971; Fairhurst, 1971; Mercer, 1985, 1996), but more reliable contextual and corroborative dating evidence is necessary to evaluate this.

Despite the wealth of climate data available, much of it specifically relevant to northern Scotland, none of it is drawn on to formulate a plausible explanation of how climate and environment interacted to force settlement change in the Strath of Kildonan. There seems to be an unconscious endeavour to not move beyond the model of settlement that links climate change, peat growth and settlement

abandonment in a causal chain reaction. O'Connell (1990) and Tipping & McCullagh (1998) have demonstrated that in some cases peat growth may result from abandonment, not the opposite. The ' nuclear winter' scenario and the distal impacts of Icelandic tephras on prehistoric Britain have been decisively refuted by Buckland *et al.* (1997). However, it should be noted that the results of the investigation by Charman *et al.* (1995) are completely ignored. The values of this study in relations to archaeological considerations is limited by fact that the sediment core was never dated and the tephra never identified, but the research showed that tephra deposition could not be demonstrably linked to deleterious effects on vegetation in the Craggie Water catchment.

Settlement Abandonment: Re-evaluating Ideas and Evidence in the Strath of Kildonan

The excavations from the Strath of Kildonan reveal little information as to how or even why these structures were finally abandoned, and less about how they might have been lived in. Re-evaluating the data, it appears that sites and structures were affected by a number of different processes, both 'natural' and 'cultural'. Burning appears to have been a frequent occurrence/ For example, the Period IV house at Upper Suigill was burnt down and ploughed over. How closely related in time were these events? Was this a deliberate burning? Could the subsequent ploughing over of the site be a symbolic re-appropriation of the land for agricultural purposes? Or was this possibly an act of aggression? Or simply an accident? The destruction of House 4 at Lairg, Sutherland (Dalland & McCullagh, 1998) and the hut at Tormore, Arran (Barber, 1997) were a result of "catastrophic" burning. In both cases it was speculated that conflict, ritual practice or accidental burning could have been the cause of the fires. The excavations at Lairg (McCullagh & Tipping, 1998) showed that identifying the real underlying cause behind the burning of the structures is challenging, But it also showed that a considered approach to excavation which takes into account site formation processes and artefact patterning can narrow down the possibilities.

Ethnographic examples from the Southwest United States show that ritual burning of structures took place after the death of individuals, and the excavated deposits usually contain human remains (Montgomery, 1996). In some cases, rooms were filled with

material from middens after burning, representing the "death" of the pueblo (Montgomery & Reid, 1990:94). Alternatively, Haury (1958) interpreted the burning of a house with large amounts of *de facto* refuse and human remains as the result of an act of aggression by a neighbouring community. In general, it is argued that ritually burned structures tend to be associated with large amounts of *de facto* refuse (Montgomery, 1996; Schiffer, 1987; Schlanger & Wilshusen, 1996). Were hut circles burned after certain members of the household or community died? Could the burning of structures in the Strath of Kildonan reflect the symbolic death of the settlement? Was this followed by abandonment, change in land use or some other shift in perception towards the settlement and its environment?

In some cases, the abandonment may be a result of processes unlikely to be discernible in the archaeological record: The Rarámuri often cited dreaming of the dead as an important factor in the decision to permanently abandon a residence (Graham, 1996). The Bahima people of Uganda are semi-sedentary pastoralists who generally move every two years, but customarily abandon places where an adult member of the group has died and been buried, but do not otherwise alter the structure (Roberts, 1996).

The discontinuity of one type of use should not imply discontinued use altogether (Schiffer, 1987). Rather, abandonment can also be used as a strategy which allows for continuity of land-use and is most apparent in transhumant systems (Cameron, 1996; Graham, 1996; Nelson, 2000). People also maintain contact with their 'homeland' because it is intimately bound up with notions of identity, community and shared history (Nelson, 2000). This might be reflected in the record from Lairg, where in the absence of human settlement, the land was used for grazing (*cf.* Tipping & McCullagh, 1998). The pollen record from Kilearnan Hill also indicates that human activity may have continued in the catchment after the inferred abandonment of the four excavated hut circles. However, since five of the structures were not investigated, it is possible that settlement continued on Kilearnan Hill, undetected by excavation.

Survey obviously reveals a great deal of information about settlement patterns, but, like excavation, is subject to its own limitations and biases (Schiffer, 1987). Visibility

remain a persistent problem. Timber built structures like those at Upper Suisgill will only be detected serendipitously. This excavation also indicates that colluviation may potentially conceal structures and features. Other structures with shallow foundations may be obscured by peat and heather growth (Ray & Chamberlain, 1985). The renovation or phasing of hut circles and other structures may not be readily apparent from field observation alone: what may appear to be simple houses representing a single phase of settlement, might on excavation, reveal occupation histories of considerable complexity and longevity (Mercer, 1985). For example, the paving stones from Hut 2 and 3 reflected extensive wear, which implies long term occupation. Additionally, the pollen records from both Kilearnan Hill and Upper Suisgill revealed a chronology of human impacts not reflected in the chronology of the excavated settlements or surveyed structures and features.

While it is true that prehistoric settlements in the Strath of Kildonan were apparently permanently abandoned at some point, there is no evidence to support the contention that these settlements "failed" because of climatic deterioration (*cf.* Cowley, 1998), or indeed volcanic eruptions. Failure and the relationship to climate change/volcanic eruptions has been assumed, rather than demonstrated. Some hut circles in the Strath of Kildonan were constructed, abandoned, maybe burned, the site and/or foundations perhaps re-used, abandoned again, subject to scavaging, perhaps ploughed over. These processes may have occurred in a combination a number of times in the life of what we perceive as a simple circle of stones.

Conclusions

Hill (2000) has criticised current approaches to the study of later prehistoric settlement change for the narrow range of questions asked and the assumptions that the can be answered in a straightforward manner: "Excavation is concerned with recovering plans, establishing chronologies, cataloguing finds...and reconstructing palaeo-economies... (p. 432). He goes on to suggest that in the process to construct 'macroscale narratives' (see also Pluciennek, 1998), the significance of every day life has been subsumed. Every day life is seen as "easy to understand" and "simple"; despite changing styles of dress, architecture or pottery the people themselves, their beliefs, perceptions and actions are immutable, a backdrop (Hill, 2000) to the large scale narratives of, for example, Later Bronze catastrophes. To illustrate Hill's point,

the excavation report from Kilearnan Hill states that excavation was undertaken in order "...[with] minimal excavation, to retrieve as much information as possible about the sites on the hillside in terms of form dating or date range and the environment current during their use." (McIntyre, 1998: 174).

The current understanding of hut circle settlement in the Strath of Kildonan is largely based on survey, supplemented with a handful of excavations. This analysis of previous palaeoenvironmental research in northern Scotland and archaeological work in the Strath of Kildonan has demonstrated that an uncritical and superficial approach to both archaeological and palaeoenvironmental data has led to an unjustified interpretation that the Strath of Kildonan was abandoned in the 12th century BC as result of climatic/volcanic deterioration. At the very least, the case remains " not proven".

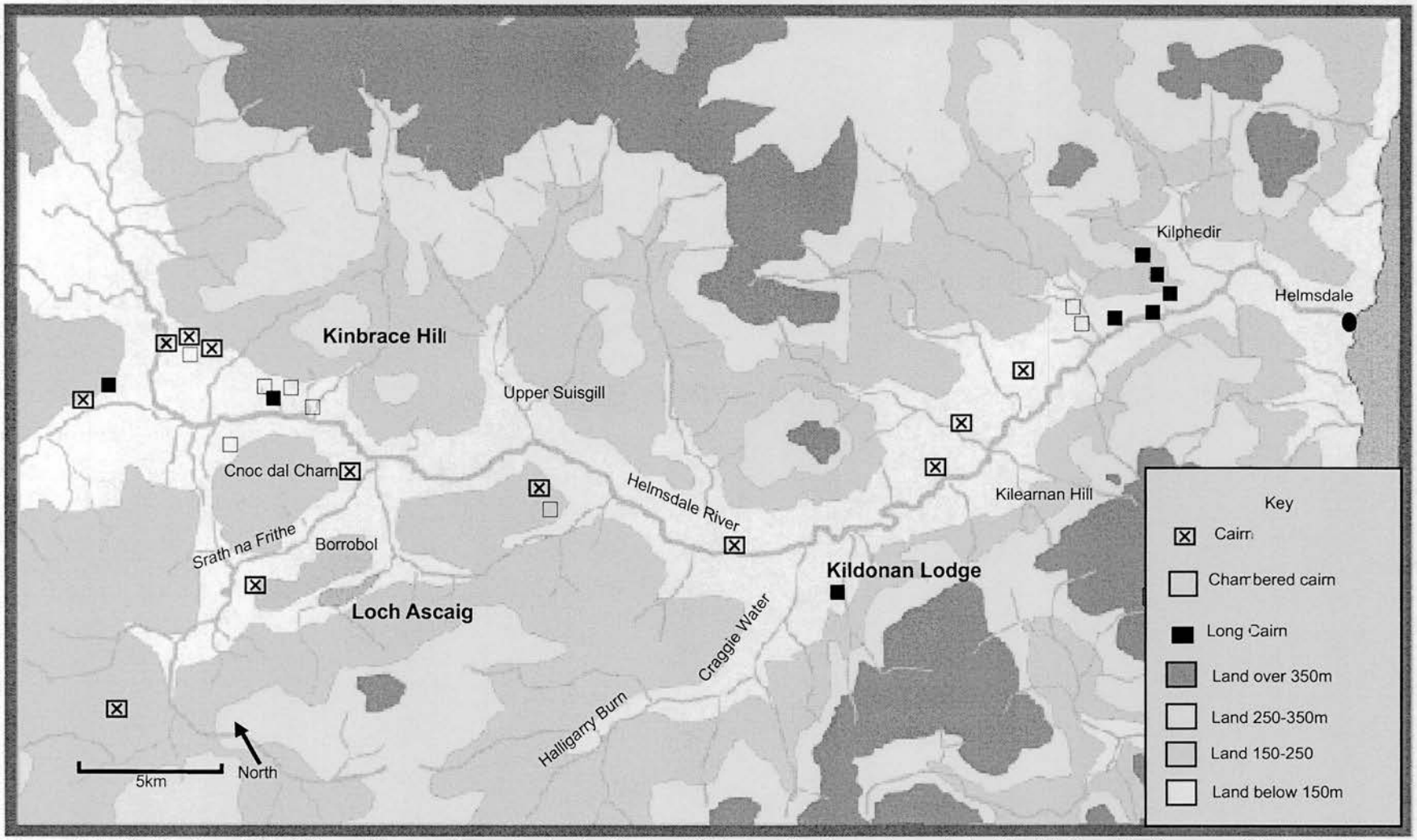


Figure 4.1. Distribution of Neolithic and Bronze Age cairns in the Strath of Kildonan. The three sites selected for this investigation are printed in bold.
Data copyright RCAHMS, 1993.

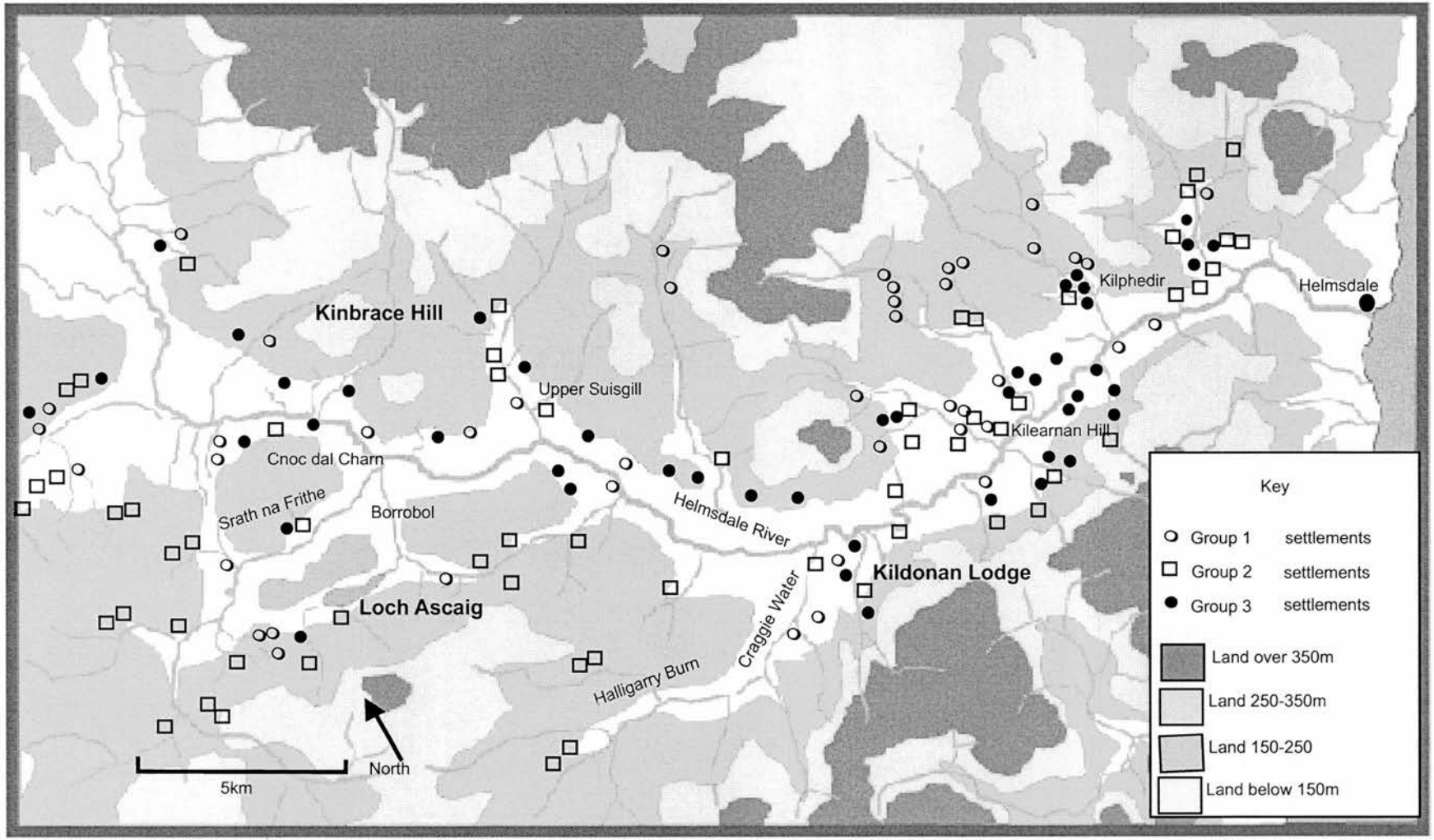


Figure 4.2. Distribution of hut circle settlement types in the Strath of Kildonan. The three sites selected for this investigation are printed in bold. Data copyright RCAHMS, 1993.

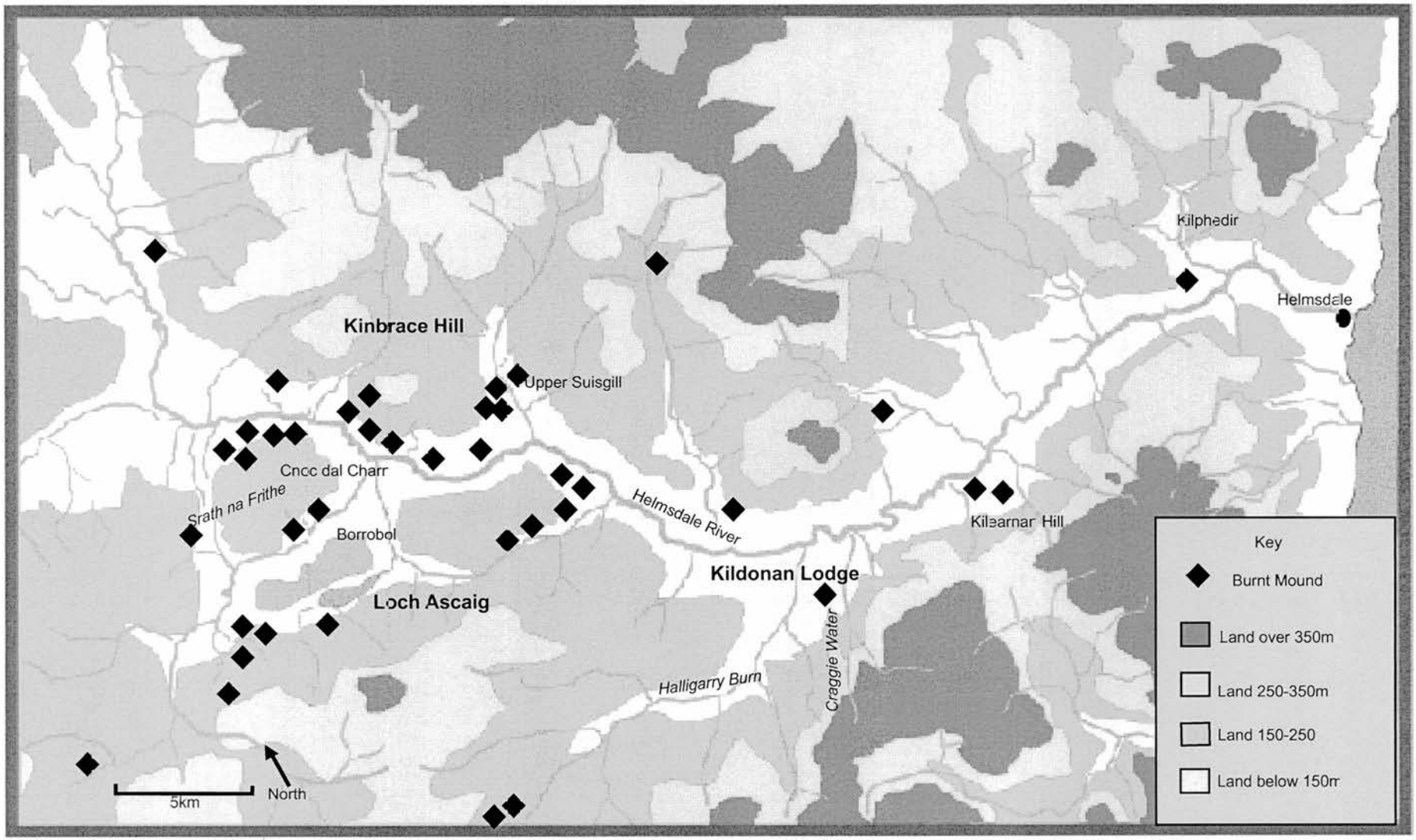


Figure 4.3. Burnt mound distribution in the Strath of Kildonan.The three sites selected for this investigation are printed in bold.
Data copyright RCAHMS, 1993.

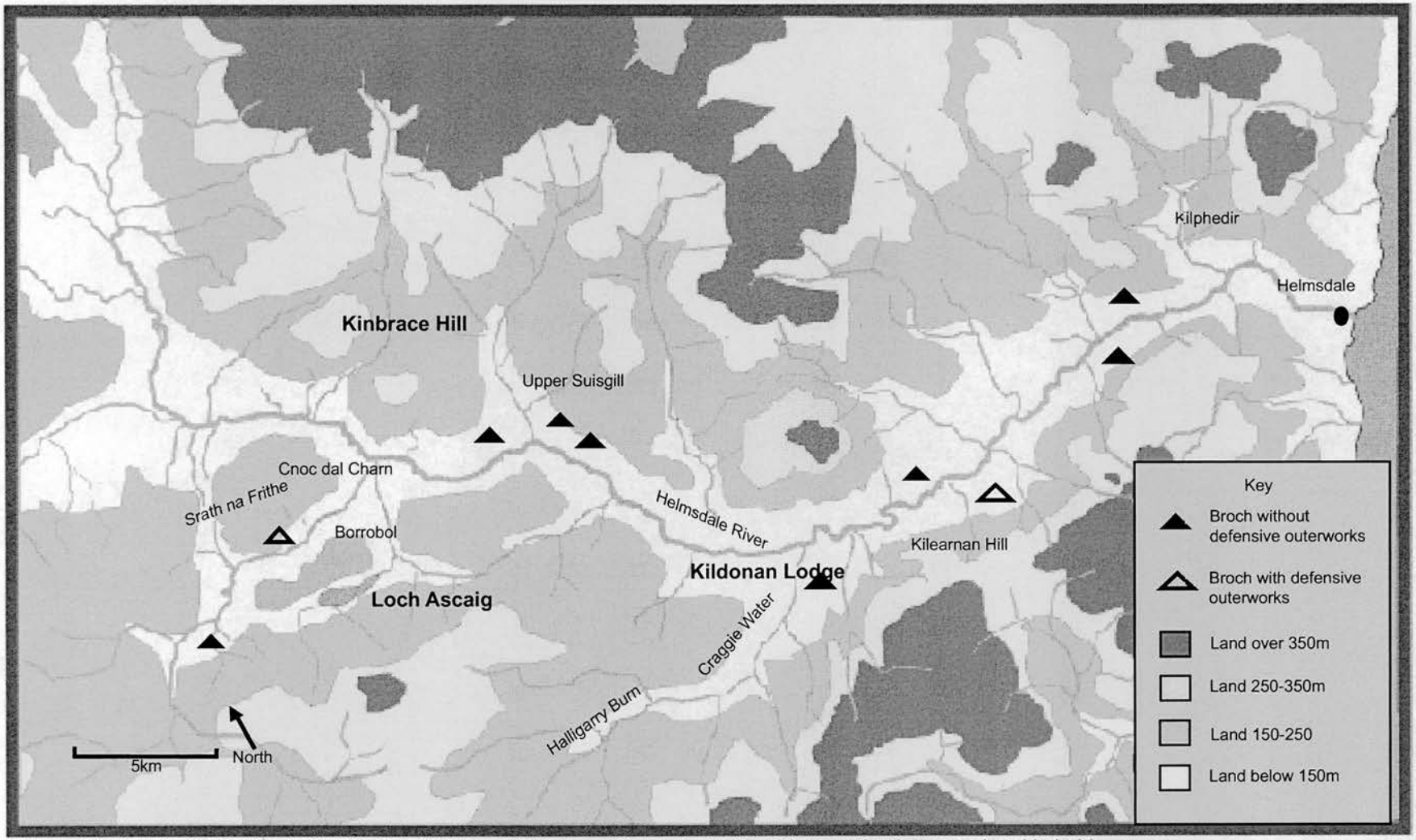


Figure 4.4. Broch distribution in the Strath of Kildonan. The three sites selected for this investigation are printed in bold.
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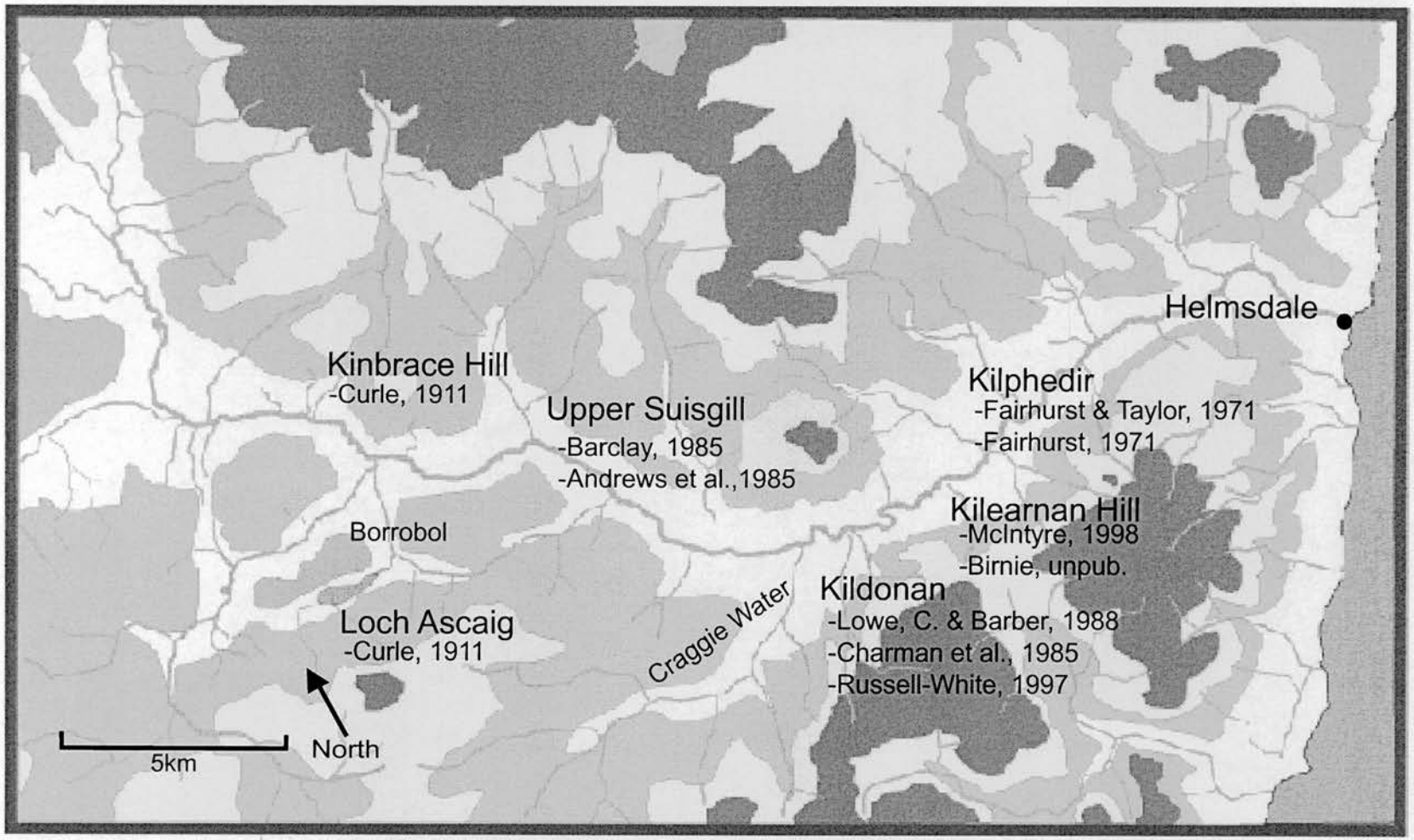


Figure 4.5. Map showing the locations of previous excavations and palaeoenvironmental reconstructions in the Strath of Kildonan.

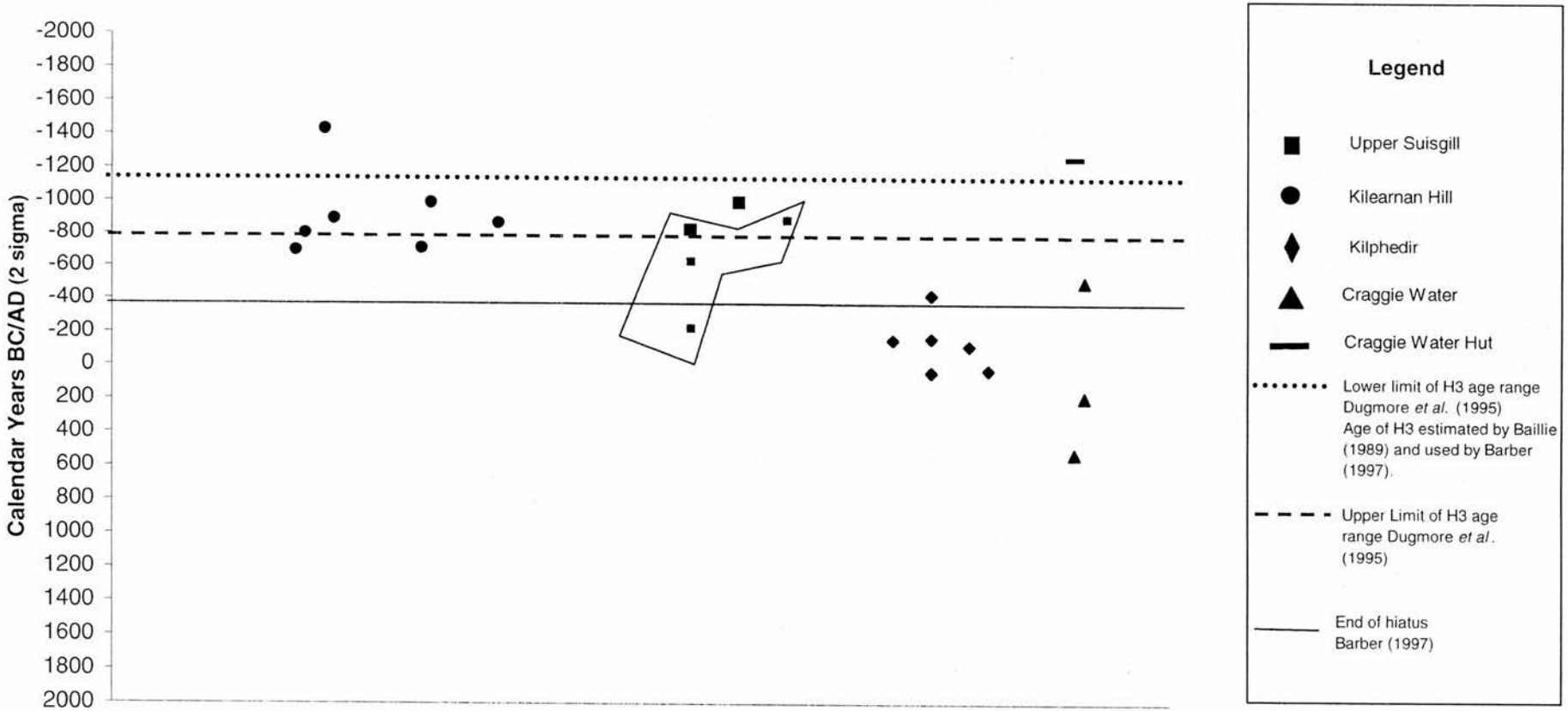


Figure 4.6. Uncalibrated 'point dates' from the Strath of Kildonan. Uncalibrated dates were most often quoted by Barber (1997) to demonstrate the apparent settlement hiatus. These were compared with the calibrated calendar ages of Hekla 3 inferred by Baillie (1989) dendrochronologically. I have also added to calibrated radiocarbon age range of Hekla 3 (Dugmore *et al*., 1995).

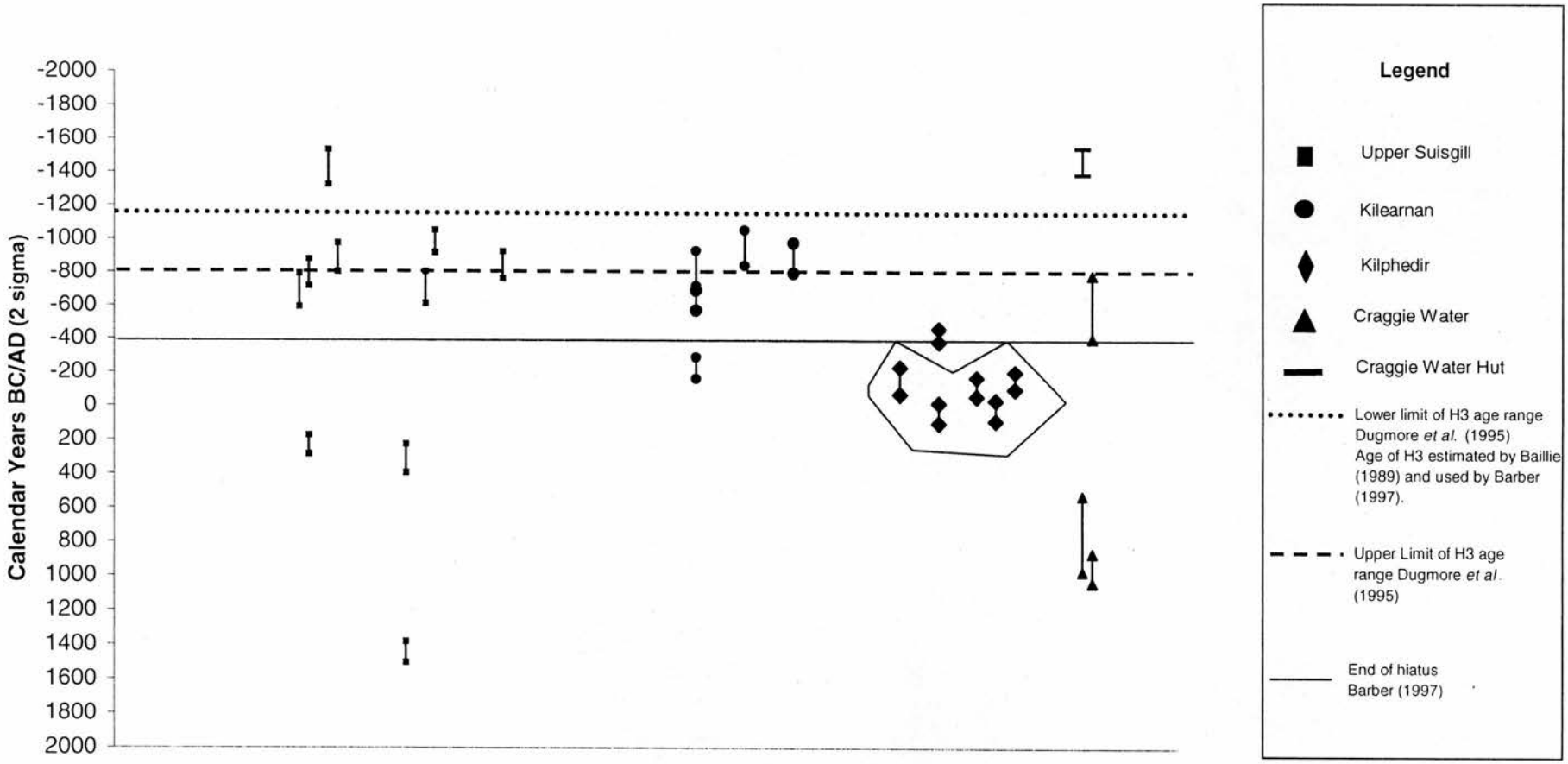


Figure 4.7. Uncalibrated calendar ages from the Strath of Kildonan.

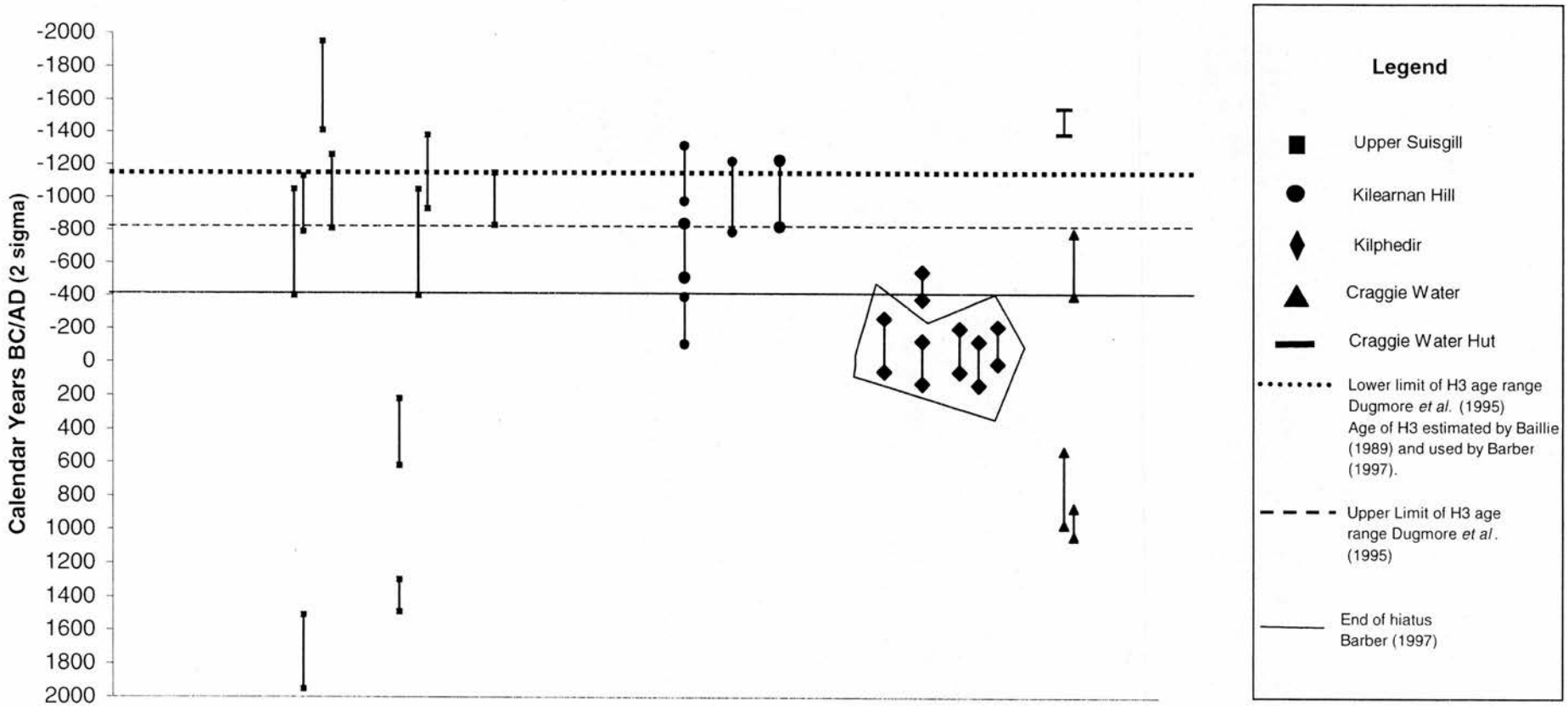


Figure 4.8. Calibrated calendar ages from the Strath of Kildonan.

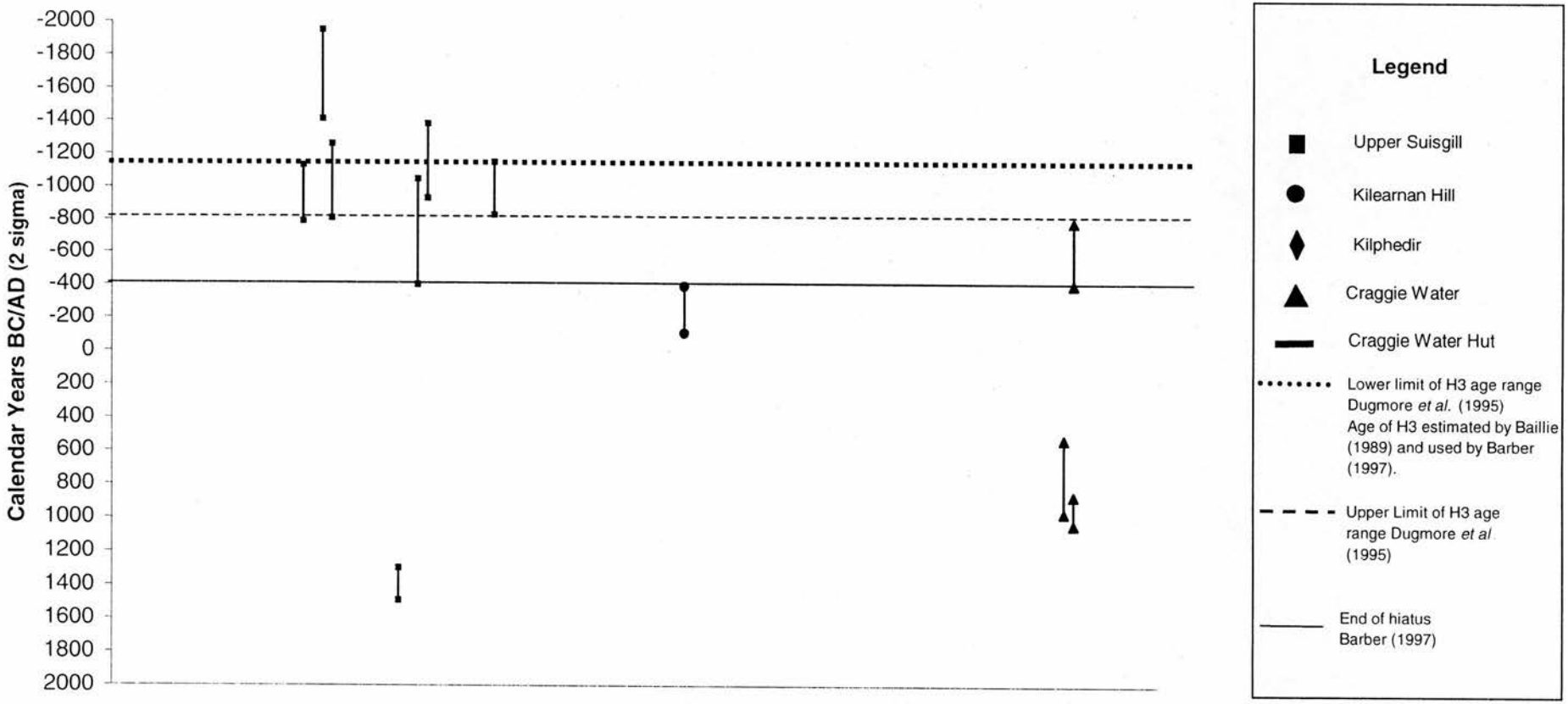


Figure 4.9. Calibrated calendar ages after excluding radiocarbon age determinations with poor contextual information or lack of clear association with structural units. Ages after Armit (1991) are also excluded.

Chapter 5

Sites and Methods

Introduction

This chapter presents and discusses the methods used to reconstruct late Holocene climate and vegetation change and evaluate the human responses to climate change. The first part of Chapter 5 details the criteria and methods used to select sites for palaeoenvironmental and archaeological study. The hypothesis of Later Bronze Age settlement abandonment is tested through reconstructing high temporal resolution climate and vegetation change from three deep bogs close by three settlement sites which are situated in settings of increasing ecological marginality. The selection process was governed by the necessity of choosing sites for palaeoenvironmental research that would exhibit sensitivity to both human impacts and climate change. The second section discusses how human activity is identified and interpreted in pollen records using a variety of indicators including not just pollen, but the presence of minerogenic material in organic peat sediments and microscopic charcoal. This section also discusses the techniques of peat stratigraphy used to reconstruct late Holocene palaeohydrological changes in peat bogs and climatic inferences. The two dating techniques applied here, accelerator mass spectrometry (AMS) radiocarbon dating and tephrochronology are also explained. Lastly, Chapter 5 discusses the handling and presentation of the data collected during the investigation. Laboratory methods can be found in Appendix I.

Selection of the Study Area

Archaeological Considerations

The Strath of Kildonan was chosen as a site where human-environment interactions can be accurately assessed because the area is currently and historically economically and environmentally marginal, in addition to possessing a rich archaeological landscape. It is believed, as has already been discussed, that the marginal nature of sites sets the parameters for their sensitivity to climatic change. Later prehistoric settlements in marginal areas are vulnerable to climate changes and therefore the risk

of agricultural failure and of the settlement itself is high. Depending on the ecological attributes, sites can be considered more or less marginal. 'Blacklands' may be seen as more marginal than 'greenlands', peripheries more marginal than cores (*cf.* Tipping & McCullagh, 1998).

The results of the previous archaeological and palaeoenvironmental investigations, which supported the abandonment hypothesis. However, as demonstrated in Chapter 4, this evidence has been shown to be inconclusive and questionable at best. The tripartite typology constructed to describe and explain settlement change in the Strath (Chapter 4; Figure 4.2), also provides a unique framework in Scottish landscape archaeology within which to investigate the relationship between later prehistoric settlement and climate change.

Palaeoecological Considerations

The site selection process must take into account, besides these basic archaeological considerations, more complex issues related to the nature of the palaeoenvironmental record. Sampling sites must be chosen which would have been sensitive to both human impact on the vegetation and palaeoclimatic changes, as well as providing high temporal resolution. Therefore, ideal sites are areas of deep peat accumulations situated close to areas of later prehistoric occupation as reflected by the archaeological record. It has been suggested that the major limitation of archaeological excavation is its inability to provide a continuous record of activity at a given site (Whittington & Edwards, 1994). For example, at Black Loch, Fife, in the absence of visible archaeological structures and features, pollen data demonstrated the periodic presence of human activity in the area from the Mesolithic, and crucially, from *ca.* 1170 cal BC onwards (Whittington & Edwards, 1994). This discussion will focus on the values of the off-site record, which can provide a valuable continuous record of landscape scale information about the ecological setting of settlements, land use and land-use change associated with archaeological structures and features (DuMayne-Peaty, 2001; Edwards, 1979, 1981, 1991; Tipping, 1994; Whittington & Edwards, 1994).

Once potential sites were identified using archaeological survey data (*cf.* RCAHMS, 1993), the second key criteria was identifying potential sites for palaeoecological

investigations. The temporal and spatial resolution of the records were of primary importance in the site selection process. The deeper the peat, the higher the accumulation rate, and thus the temporal resolution of the record. The temporal resolution of the record is also dependent on sampling intervals, which is discussed in more detail with the laboratory methods. The spatial resolution of pollen records is much more complicated. Pollen analysis conducted using long records from peat bogs or lakes with the intention of reconstructing general landscape and vegetation change in relationship to past occupation sites and attendant human activities is called 'off-site' pollen analysis (Edwards, 1979). Analysis of samples derived from organic deposits in archaeological contexts, such as wells and latrines, is known as 'on-site' pollen analysis; in Chapter 4, examples were of analysis from soils in souterrains (*cf.* Pollock, 1992) and a fossilised field system (*cf.* Tipping, 1998). These offer very localised and context-specific 'snap-shots' of vegetation associated with particular areas of sites at particular times (Dumayne-Peaty, 2001).

Pollen Source Area and Representivity

Much of the early work of pollen representivity was concerned with developing models of pollen transport to small hollows in woodland landscapes, *eg*, Tauber (1965) and Anderson (1970). These models were refined by Janssen's (1966) distance-decay model and Webb's (1978) work on the influence of basin size on pollen representivity. Building on this previous work Jacobson and Bradshaw (1981) produced a model of pollen source area and representivity that is widely applied in palynological studies. The pollen source area is controlled by the diameter of the basin which influences the relative proportions of local, extra-local and regional pollen reaching a site (Figure 5.1):

- Local pollen is derived from plants growing within 20 m of the sampling site.
- Extra-local pollen originates from plants growing between 20 m and several hundred metres away.
- Regional pollen is transported to the sampling site from much greater distances.

For example, a site *ca.* 250 m in diameter would receive pollen primarily from extra-local sources; a site 50 m in diameter would record mostly the local component of the

vegetation. The size of the basin is not the only control on the source area and representivity of pollen. Because the pollen productivity and dispersal characteristic for individual plants are different, each taxon has, in effect, its own pollen source area. For example, *Salix* produces large amounts of pollen, but the grains are sticky, tend to clump and this plant is insect pollinated, thus, it is suggested that *Salix* pollen percentages of just 2-3% total land pollen (tlp) indicate local growth (Tauber, 1965). This is in contrast to *Pinus*, another productive taxon, which is wind pollinated. The grains of *Pinus* are characterized by sac-like structures which enable it to be transported over long distances. Thus, some have suggested percentages as high as 20-25%tlp are reliable indicators of local growth. Lakes are subject to particular issues of pollen representation and deposition caused by, for example, mixing of pollen in the water, and re-suspension and sediment mixing after deposition (Sugita, 1993) and, unlike peat bogs, the aquatic component is easily separated in the pollen assemblage reducing the complications of arising from surface pollen assemblages on mires (Bradshaw, 1991). Surface pollen studies of *Calluna vulgaris* (heather), one of the most common plants on NW European peatlands, have shown a linear relationship between the abundance of *Calluna* pollen and *Calluna* plants within 1m of each site, which is useful for the interpretation of pollen assemblages from peatlands (Evans & Moore, 1985).

Pollen source areas are not static and the interpretation of fossil pollen assemblages is complicated by vegetation changes through time (Birks & Gordon, 1988; Prentice, 1985). As such, models of pollen representation and source area are only a 'best estimate' (Hjelle, 1998). In densely wooded landscapes, as the canopy opens up, this increases the amount of extra-local and regional pollen arriving at the site; estimates of pollen source area then need to be revised appropriately (Jacobson & Bradshaw, 1981; Prentice, 1985). Pollen productivity and dispersal characteristics of different plants is a significant aspect of pollen representation and estimates of pollen source area (Anderson, 1970; Prentice, 1985). High pollen producing species which are wind pollinated and have a higher dispersal capacity, such as *Pinus*, will have a different source area than low growing herb species, especially since many of these are insect-pollinated. As vegetation changes, it will alter the relative proportions of the different components of the pollen rain illustrated in Figure 5.1. Work has been done to calibrate the representation of agricultural indicator species but because of

the influence of edaphic conditions on pollen productivity, such estimates have only very localized applications (Hjelle, 1998).

Aspects of pollen representivity and relationship to vegetation have become increasingly refined, contributing to a more detailed understanding of pollen productivity, source area and representation (*eg.*, Bradshaw, 1988; Calcote, 1998; Jackson & Wong, 1994 Prentice, 1985, 1988; Sugita, 1993 1994). Studies have found that sampling in isolated areas of forest situated in open landscapes may result in a misleading high correlation between pollen representivity and plant abundance (Jackson & Wong, 1994). The work of Jackson and Dunwiddie (1992) examined the effects of spatial isolation on pollen representation by studying and comparing pollen dispersal and transport to off shore islands and densely forested mainland landscapes and demonstrated that models of pollen representation to islands can be applied to patchy terrestrial landscapes, *eg.*, isolated forest stands in peatlands.

Pollen production and dispersal are also affected by human interference in the vegetation. (Aaby, 1988; Moore *et al*, 1986; Groenmann-van Waateringe, 1993; Rackham, 1980). Disturbance of the woodland can increase flowering and pollen production of trees, increasing pollen representation inverse to plant abundance (*cf.* Aaby, 1986). Groenmann-van Waateringe (1993) found that grass pollen productivity was actually higher in a heavily grazed productive forest than in a lightly grazed unproductive forest. This, she noted, presents a problem for interpretation of fossil pollen assemblages might reflect high tree pollen indicating a densely forested landscape unsuitable for grazing, when in actuality it may be reflecting a highly productive, heavily grazed woodland or pasture on the woodland margin. A series of empirical and modelling studies (Bröstrom, *et al*, 1998;Gaillard *et al*, 1992; Sugita *et al.*, 1998) have highlighted the problem of quantifying the extent of woodland clearance from fossil pollen assemblages. For an area of southern Sweden Sugita *et al.* (1999) suggested that the finest spatial scale which woodland clearance and vegetation types could be differentiated was 800-1000m.

More recently it has been argued that theoretical models developed for woodland landscape do not provide an appropriate basis for understanding issues of pollen productivity, dispersal and transport in open landscapes, such as those characteristic

of northern Scotland (Bunting, 2002; Fossitt, 1994a). The low growing nature of peatland vegetation, for example, means that the dispersal components of the pollen rain need to be modified (Fossitt, 1994a). Wind speed, precipitation and exposure are another influence on pollen representation, all of which are comparatively high in northern Scottish landscapes. Although increase in non-tree pollen can be expected as deforestation occurs, arboreal pollen can often be over- represented in pollen diagrams from open landscape because of the high productivity and dispersal capacity of many tree types (Anderson, 1970; Jacobson & Bradshaw, 1981; Sugita *et al.*, 1999). Reliable estimations of the background component of pollen assemblage are necessary before non-arboreal pollen percentages can be used to estimate the extent of openness in past landscapes (Bröstrom *et al.*, 1998).

Small diameter basins provide a record of the most local and site specific changes in vegetation and the emphasis on small forest hollows may not only be inappropriate because of the increasingly open nature of the upland Scottish landscape since the late Holocene. Small hollows recording predominantly local forest types will be dominated by pollen transported within 20m of the site, and as such, vegetation changes of interest in an archaeological sense may be minimised or undetected altogether (*cf.* Edwards, 1979, 1982, 1991, 1993). In a discussion of Bradshaw (1991, Edwards (1991) additionally noted that it is unlikely that small hollows will consistently be located within 100m of occupation areas. To this it could be added that humans would also be unlikely to restrict activities to a few tens of metres around a site. Survey indicated that field systems in the Strath of Kildonan could measure up to 30 or more hectares (RCAHMS, 1993). Poor chronological information related to structures and features, along with visibility of sites, also means that it is impossible to know where occupation may have been concentrated at different times.

Given the uncertainty relating to the chronological and spatial dimensions of the archaeological record, a more generalised approach to reconstructing human impacts was adopted for the current investigation. Edwards (1981; also Edwards & McIntosh, 1988) have suggested that sites selected at the edge of large peat bogs can provided a general picture of human activity, *eg.*, clearance, fire, grazing and arable activities. The 'extent' and 'intensity' of activity cannot be inferred with any certainty from these reconstructions (Edwards, 1981). These might be resolved with further work

using small hollows if finer spatial resolution of vegetation change is required, and if such sites are available (Edwards, 1991). It is important to recognise that the larger pollen source areas of the mire edge sites will reflect an aggregate of various 'natural' and 'cultural' vegetation changes (Edwards, 1991). For the purposes of this research, the key issue is to be able to identify human impacts relating to marginal areas of the landscape, rather than provide fine spatial scale reconstructions of vegetation change. In this respect, the selection of sites emphasised the more general approach to vegetation reconstruction proposed by Edwards (1981, 1991) in an effort to maximise the possibilities of detecting human impacts in relationship to known or potential occupation sites.

The pollen record is the primary proxy of human activity in the catchment. As such, it plays a valuable role in both directing and complementing archaeological research. As alluded to in Chapters 3 and 4, identifying the scale and 'integrated-ness' of later prehistoric settlement is a continuing problem in archaeology. AMS dating provides a more reliable basis (than bulk samples; see below) for comparing records of vegetation (and palaeoclimatic change) from different sites, but tephra horizons offer a more precise means of correlation where they exist (Dugmore, 1989). The comparison of continuous records of vegetation and human impacts from different sites can assist towards developing and understanding of the complex interactions of the different scales of settlement and subsistence systems (Figure 5.2).

Palaeoclimatic Considerations: Choosing Sensitive Sites

Reliable and accurate records of past climate variability and vegetation change are critical to assessing the theory of a Later Bronze Age catastrophe. Although comparison with proxy climate records from other areas is important to understanding the regional context of climate change, records need to be constructed which reflect the conditions specific to the sites in this study. Thresholds are dependent on local conditions (Barber, 1982; Blackford, 1993), and it would be unwise to assume that, for example, the climate change changes detected by Anderson (1998) in Wester Ross would be contemporaneous or even recorded at all in peat bogs in the Strath of Kildonan. Moreover, attempting to explain the human response to climate change using such data would be meaningless. The construction of proxy records of palaeoclimate variability in parallel with palaeoecological reconstructions of human

activity from the same cores, provides a more reliable basis for interpreting site-specific climate-human interactions.

As briefly touched upon in Chapters 1 & 2, the principle source of data concerning terrestrial proxy climate change in Britain and NW Europe has been ombrotrophic peat bogs (*cf.* Aaby, 1976; Barber, 1981; Blackford, 1990). Ombrotrophic, peatlands are characterised by their convex profile which means they are 'raised' above the surrounding land surface (Moore & Bellamy, 1973). Because of their raised situation, they only receive moisture from the atmosphere, and the runoff from the mire surface may result in the growth of a 'ring' of fen vegetation around the base of the mire called the lagg (Charman, 2002). Although mire hydrology is usually a composite of a number of autogenic and allogenic processes, climate is considered to be the overarching control on the growth and development of raised mires (Barber, 1981). Stratigraphic changes in this type of mire are usually visible as sharp changes in the colour and compositions of the sediment, *eg.*, the *grenhorizont*, discussed in Chapter 1.

Blanket bog is another type of peatland, a term which is a catchall for several different types of mire complex (Charman, 2002). Like raised bogs, the growth of blanket peat is dependent on a number of different climatic controls including high annual precipitation (>1000mm) and low summer temperatures (<15°C monthly average) (Lindsay, 1995). Unlike raised mires, blanket peats do not usually exhibit varied or prominent visual changes in sediment stratigraphy; macrofossils are usually rare and organic matter well decomposed. For these reasons it was believed that blanket mires and topogenous (basin) mires could not provide sensitive records of palaeoclimatic fluctuations (Blackford & Chambers, 1991). The hydrology of these mire complexes is further complicated because their growth and development in a number of topographical settings, such as saddles, spurs, and floodplains, where they may be exposed to runoff from the surrounding topography or are vulnerable to flooding. Despite these potential drawbacks, a number of studies have shown that blanket and topogenous peats can also yield high quality records of palaeoclimatic change (Anderson, 1998; Blackford, 1990; Blackford & Chambers, 1991; Chambers *et al.*, 1997). Saddle mires have been chosen in some cases, because their water-shedding nature is somewhat analogous to ombrotrophic peat bogs (*cf.* Blackford & Chambers,

1991; Chambers *et al.*, 1997). Topogenous bogs can also be used when they are isolated from inflowing streams and predominantly ombrotrophic; basin peats also have the advantage of providing relatively deeper accumulations of peat than blanket mires (Anderson, 1998).

The work of Barber *et al.* (1994) developed a 'climate response model' which inferred changes in mire surface wetness from changes in mire surface vegetation. The results of the investigation showed good agreement between historical climate records (*cf.* Lamb, 1977) and variation in the record of plant macrosfossils, although is not clear whether the mire is responding primarily to changes in precipitation or temperature. Recent work by Charman and Hendon (2000) has indicated that temperature may be more important than precipitation, but this needs further investigation. More recently, it has been demonstrated that the timing and occurrence of major palaeohydrological shifts, measured by the degree of peat humification, are the same or similar between and within mires, also supporting the inference that climate is the major controlling factor in mire hydrology (Barber *et al.*, 1998). More recently, two separate studies have reconstructed parallel records of proxy climate change from speleothems and peat bogs. (Baker *et al.*, 1999). The good agreement in variations in these two records indicates that both systems are responding to some aspect of the climate.

There are several unresolved issues concerning the precision and accuracy of the peat bog archive which must be considered. The primary limitation of the method is the lack of quantification of the results (Blackford, 1999, 2000). Work is currently underway to develop proxy measures of water table depth using testate amoeba (Charman & Hendon, 2000; Woodland *et al.*, 1998). This approach is still in its infancy and its efficacy is limited to *Sphagnum* peats (Jackson, *pers comm.*) (the peats in this investigation are primarily sedge peats). A second possible approach is highlighted by the use of parallel speleothem and peat bog records. This method, however, is severely geographically limited to areas like Assynt in NW Sutherland where the study was based, where peat bogs are situated over limestone caves containing stalagmites. Dating precision remains, as ever, one of the primary limitations in proxy climate reconstruction, although more widespread use and development of tephra horizons, where possible, and other radiometric techniques

such as wiggle-matching (*cf.* Kilian *et al.*, 1995) might help in the correlation of records (*cf.* Blackford, 1998, 2000).

Chapter 2 (Table 2.1) highlighted the good temporal relationship in shifts to wetter conditions from NW European peat bogs. More recent work by Anderson (1998) has shown the potential relationship between palaeohydrological shifts in NW Scotland and North Atlantic regional scale climate variation. In general, the work on mire palaeohydrology which has spanned the last thirty years indicates that study of peat humification is a reliable and robust method of proxy climate reconstruction.

The Three Sites

Sites were selected on a gradient of increasing marginality, reflected by the respective density of settlement types and ecological attributes which have been used to construct current concepts of marginal environments (Figure 5.3). The Kildonan Lodge site was originally recommended by Dr. Richard Tipping of the Department of Environmental Science, University of Stirling, based on previous field work he had conducted in the catchment. Two other sites were selected for investigation after several weeks of field work between October 1999 and September 2000:

Kildonan Lodge . The Kildonan Lodge site is a small in-filled former lake, situated at 50.0 m OD (58°8'54''N/3°50'34'' W). Kildonan Lodge reflects a typical lowland setting (Figure 5.4). The estimated pollen source area is illustrated in Figure 5.7. It is very close to well preserved multi-period archaeological sites (Figure 5.7; Appendix III) and the historic valley-floor settlement core, although today the locality is typified by shallow blanket peat and is of lower agricultural productivity in the agricultural core of the Strath of Kildonan. Settlement in this area was predicted to be the most viable of all the sites in this study because of its ecological setting and the density of Group 3 settlements (Figure 4.2). Kildonan Lodge has a relatively sheltered position, protected to the south and SW by the steep slopes of The Creagan and Cnoc Craggie. Cereal cultivation was practiced on the terraces above the Helmsdale River until the late 19th century. The catchment is bounded on two sides by modern conifer plantations. Small stands of *Betula/Quercus* and *Sorbus aucuparia* woodland survive where they are protected from grazing.

Loch Ascaig is a large topogenous mire situated in an infilled area of basin formerly occupied by Loch Ascaig at *ca.* 50 m OD (58°12'27'' N/3°58'49'' W) near the western shore of Loch Ascaig (Figure 5.5). The two cores were extracted from an area of deep peat near the edge of the mire adjacent to areas of later prehistoric settlement remains; the estimated pollen source area and its relationship to occupation areas is illustrated in Figure 5.8. As can be seen from Figure 4.2, prehistoric settlement here is represented mainly by Group 2 settlements and a handful of Group 1 settlements and more intermittent human impacts should be registered in the palaeoenvironmental record (*cf.* Cowley, 1998; RCAHMS, 1993) There is extensive archaeological evidence of agricultural production, including lynchets, banks, walls as well as patches of cord rig (Figure 5.8; Appendix I). Situated on the slopes of Ceannabhaid and Mid Hill are the remains of several hut circles and the area is today maintained as improved pasture for sheep grazing. Settlement should have expanded into this area when environmental conditions were favourable, and abandoned when conditions deteriorated. Although lower in altitude, the settlement remains around Loch Ascaig occupy a very exposed position with little shelter from the wind and weather Despite the name Ceannabhead, which means 'Birch Head', the predominate vegetation consists of lowland heath communities and recent conifer plantations represent the only woodland growth.

Kinbrace Hill is located at *ca.* 240 m OD (58°14'38''N/3°53'45'' W) the cores were extracted near the shedding edge of a large saddle mire (Figure 5.6). The estimated pollen source area is illustrated in Figure 5.9. This site should be the least agriculturally viable of the three sites; where human impacts are predicted to be minimal to non-existent. Kinbrace Hill is in a highly exposed location with little protection from the strong, prevailing westerly winds. The vegetation is characteristic of wet, upland heaths. There is no natural woodland extant, although the south facing slopes of Kinbrace Hill are covered by an extensive area of modern conifer plantations. The area has not undergone the intensive archaeological survey applied to other areas of areas of the Strath, especially Kildonan Lodge (*eg.*, Lowe & Barber, 1988; Russell-White, 1997). There are two areas of dense multi-period settlement below the Kinbrace Hill site, one to the NE of the sampling site, near Creag nan Caorach ('Crag of the Sheep') and the other located along the SW slopes of Kinbrace

Hill, adjacent to the Helmsdale River (Figure 5.9). The archaeological evidence from survey is summarised in Appendix II.

Situated between Cnoc na h-airgh and Cnoc na fliuch-airigh and along the Kinbrace Burn, are the remains of several shielings. The names Cnoc na h-airigh and Cnoc na fliuch-airigh translate as 'Shieling Hill' and 'Hill of the Wet Shielings', respectively. Although the antiquity of these names is difficult to assess, it is clear from place-name and archaeological evidence, that the area around Kinbrace Hill functioned in later periods as part of a transhumance economy. The strategy behind the sampling of this site is to investigate: 1) whether or not pollen analysis from the site can 'predict' the presence of human activity where archaeological survey has failed (*cf.* Edwards & Whittington, 1994) and 2) if the expansion of human activity into the uplands can be detected at critical times, *ie.*, in relation to evidence for climate change, in the palaeoecological reconstructions from this most marginal location.

The site has been the subject of two previous studies. The first, by Lowe and Turney (1997) established the presence of the Vedde Ash, *ca.* 10,300 ^{14}C year BP, on the Scottish mainland. Its significance is as a marker for correlating sequences for the onset of the Younger Dryas stadial (Austin *et al.*, 1995). The second investigation by Charman *et al.* (1995) was to establish the record of tephra fall, using similar methods of sediment geochemistry to those discussed in Chapter 5 and to evaluate the potential impact on soils and vegetation using pollen analysis. The results and limitations of their findings were covered in detail in Chapter 4.

The 'Personality' of the Strath of Kildonan

The Strath is surrounded by a rugged topography, glimpsed in Plate 5.3, that effectively isolates it from neighbouring straths. Besides its latitudinal location, high exposure and rainfall, the nutrient poor, acidic nature of the soils (Futty *et al.*, 1982) also contributes to the marginality of the area. The Strath of Kildonan is characterised by a complex geology which is summarised only briefly here. As with much of Sutherland, the underlying geology is primarily made up of rocks of the Moine Series. The rock is a mixture of mica-schists (derived from shales), quartzite and silicieous (derived from sandstone) or semi-pelitic granulites (everything in between the other two). Basic intrusions are a minor part of the Moine series, these are

responsible for the outcrops of steatite in northern Scotland (Gibson, 1922), and in the Strath of Kildonan are confined to a scattering of hornblendes. The Moinian rocks are often interrupted by igneous intrusions of the Strath Halladale complex. The presence of gold near Upper Suisgill is a result of the dense cluster of intrusions in this area. The gold, found in small quantities in outcrops of granite and migmatites was weathered out during the Tertiary period settling into the gravels of the river beds and concentrated by the stream action (Read, 1931).

The drift geology of the Strath of Kildonan is confined largely to morainic drift deposits, overlain by peats in some areas, and alluvial sediments along water courses (Futty, 1982). Near the coast, where the Helmsdale River empties into the North Sea, the solid geology is predominately Helmsdale Granite. Here, the overlying drift soils are a mixture of peats, morainic drifts, alluvium and blown sand on the coast. The coast itself is a narrow strip of the Old and New Red sand stones, which are more prominent in Caithness, to the north. The acidic nature of these rocks gives rise to the mainly acid nature of the soils in the catchment. Climate also affects soil formation because processes such as leaching and gleying are largely dependent on rainfall and temperature, which, in northern Scotland, are themselves dependent on altitude and the influences of the North Atlantic depression tracks (Futty *et al.*, 1982). Soils in the Strath belong mainly to the Arkaig association of soils derived from Moine Series rocks.

The Scene is Set...

With an understanding of the nature of later prehistoric settlement in the Strath of Kildonan as it is currently understood, the personality of the place which gives rise to perceptions of its marginality it is now possible to consider how the pollen and peat stratigraphic records function to allow a reliable evaluation of the relationship between later prehistoric settlement occupation and climate change in the Strath of Kildonan.

Field Methods, Coring and Storage

Transects were taken to find the areas of deepest peat at each site using an Eijelkamp corer. At Kinbrace Hill and Loch Ascaig, areas of deep peat close to the mire edge

were sampled in order to maximise the potential for detecting subtle human impacts (*cf.* Edwards, 1979, 1981, 1991). Coring was carried out using a 100 cm long, 6.0 cm diameter closed chambered Russian corer. Its advantage over other corers is that sediments are recovered with minimal disturbance and risk of contamination (Jowsey, 1966). Two cores of 658.0 cm in depth were extracted at Kildonan Lodge in October 1999. Two cores of 435.0 cm in depth were extracted from Kinbrace Hill in October 2000. The top 8.0 cm were not sampled because of the poorly humified, fibrous nature of the sediment. In October 2000 two 660.0 cm cores were extracted from an area of deep peat (up to 11.0 m) near the edge of the mire. The top 80.0 cm could not be sampled because the sediment was very poorly humified and unconsolidated. All cores were transferred to plastic guttering, sealed in plastic and after being transported back to the Department of Geography, University of Edinburgh, stored in a cooler at 4°C. Laboratory methods for the preparation of pollen samples, colorimetric analysis of the degree of peat humfication, loss-on-ignition and preparation of tephra samples for EMP analysis are detailed in Appendix IV.

The Identification and Interpretation of Human Activity in the Palaeo-archive

The Pollen Record

Below is a discussion of the various problems and approaches to elucidating past human activities in the palaeoecological archive. The discussion of identifying agricultural practices in pollen diagrams is characterised by more *caveats* than definitive guidelines, however, despite some of the limitations, pollen analysis is still considered a reliable and useful method for assessing broad patterns of agricultural activities associated with archaeological settlements (Dumayne-Peaty, 2001; Maguire, 1983; Tipping, 1994).

The use of 'indicator species' (Behre, 1981) is a well established means of identifying and differentiating different types of human impacts on vegetation. It has been argued, however, that the precise reconstruction of prehistoric vegetation communities is not possible because the habitat requirements and adaptive capabilities of individual taxa are not permanent through time (Berglund, 1985;Gee & Giller, 1988). For example, drainage is a relatively new feature of the British agricultural landscape and ancient

fields may have possessed a more diverse wetland flora (Hillman, 1988). Hillman (1988) has also shown that changes in methods of cultivation have resulted in the development of different weed floras characteristic of arable agriculture. His example was based primarily on the switch from the ard to the mouldboard plough in late 20th century Turkey and Syria, but his contention was also supported by experimental work carried out at Butser Ancient Farm in Hampshire.

The separation of natural vegetation dynamics from human interference can be problematic and management of woodland poses particular interpretive problems. For example, coppicing will cause alterations in the pollen productivity of some tree types; *Corylus avellana* increases its pollen productivity substantially (Rackham, 1980), and in some situations could obscure human impacts, and thus give the false impression of abandonment. However, such processes are difficult, if not impossible, to 'prove' (Edwards, 1993; Edwards & Whittington, 1998). Regular pollen fluctuations in tree taxa were observed in the pollen profile from Glen Affric during prehistory, and although woodland management was tentatively inferred, it was also noted that the pollen fluctuations were similar to much earlier patterns interpreted as part of natural woodland processes (Davies, 1999). Pollen cores from small hollows in areas where tree cover is extensive and the taxa are prolific pollen producers, will record mainly local effects, and thus human impacts may appear weak (Hicks, 1988).

Cereal type pollen is, of course, an obvious indicator of arable activity, but its use is not without its limitations. Cereals except for *Secale* (Rye), are self-pollinating, and this, coupled with the large size of the pollen grains, means that the grains are not widely dispersed, and usually under represented in pollen diagrams. Edwards (1993) has observed that because of pollen representivity issues, and especially those associated with cereal type pollen, proving the absence of farming is difficult. The family of plants to which cereal belongs has a characteristically uniform morphology, unlike many other types of grains, making genera and species level differentiation difficult (Maguire, 1983). Anderson (1979) (Table 5.1) devised a system of classification based on annulus diameter, surface sculpturing and size of the pollen grain, however, it is often the case that grains are too damaged to be confidently assigned to a level more specific than 'cereal-type'. Because of the dispersal and pollination characteristics of cereal pollen, its presence in sediments is usually taken

as an indicator of the growth of the plant (Vuorela, 1973). Problems of differentiation of pollen types are not limited to Cerealia. The families Chenopoadiacae, Crucifereae and Brassicaceae all contain genera and species of vegetable or herbs consumed by people, weeds characteristic of different types of arable and pastoral environments, as well as other plants which grow in a variety of natural ecotones which cannot be reliably separated.

Table 5.1 Cereal groups.[a]

Wild grass group	Mean annulus diameter: <8 μm, mean grain size: <37 μm, surface: scabrate verrucate.
Hordeum group	Mean annulus diameter: <8-10 μm, mean grain size: <32-45 μm, surface: scabrate.
Avena-Triticum group	Mean annulus diameter: >10 μm, mean grain size: >40 μm, surface: verrucate.
Secale cereale	Mean annulus diameter: <8-10 μm, oblong outline surface: scabrate.

[a] after Andersen (1979)

Edwards (1979) observed that many pollen types thought to be primarily pastoral indicators can also represent the growth of field edge weeds, and resulting pollen assemblages might incorrectly be interpreted as representing a mixed farming economy. A principle concern of using an indicator species approach is that it makes unprovable assumptions about long term trends in the ecological tolerances and phytosociological preferences of plants (Maguire, 1983). A significant amount of work has been done in an attempt to use ratios of indicator species to assess the emphasis on pastoral or arable agriculture in fossil pollen assemblages (Godwin, 1968; Turner, 1964; Roberts *et al.*, 1973). However, the validity of the approach has been questioned on the basis of the ambiguity associated with assigning indicator species to specific classes (*ie.*, arable or pastoral) and the relative lack of understanding concerning pollen production and dispersal of indicator species (Behre, 1981; Maguire, 1983; Gaillard *et al.*, 1992).

Some consider *Rumex* primarily an indicator of arable activity (Riezebos & Slotboom, 1978), while others have employed it as a pastoral indicator (Berglund, 1969; Donaldson & Turner, 1977). Thus, the narrower the ecological range of a particular taxon, the more useful it is as an 'indicator species' (Dumayne-Peaty, 2001). Modern

pollen-land use relationships have been investigated in an attempt to differentiate agricultural activities beyond merely arable/pastoral mixes, but to use a combination of comparative methods and indicator species to identify, for example, fodder-growing meadows (Gaillaird, *et al.*, 1992). Bröstrom *et al.* (1998) stressed that modern analogues are only comparable with fossil pollen spectra from the same region. When a taxon is near its ecological threshold, pollen productivity and dispersal may be affected (Hjelle, 1998). Tipping (1994) noted that the construction of modern analogue approaches for calibrating the vegetation detecting properties of fossil pollen assemblages has yet to receive its due attention in Scotland.

Pollen transport mechanisms, filtration by the woodland edge and woodland management may all contribute to the exclusion of unambiguous evidence for human impacts from the pollen record. It is not the intention to present the interpretation of pollen data in a completely negative light. In order to exploit the full potential of pollen analytical studies in archaeological interpretation, palaeoecologists and archaeologists alike must move beyond traditional and mechanistic perspectives of subsistence practices. Identifying and qualifying human activities from one line of evidence alone is clearly problematic. Hicks (1988) has argued that because there will be several activities occurring simultaneously, the pollen assemblage will not reflect any one activity distinctly, but acts as a composite record of several different activities. Edwards (1988) has recommended that only broad categories of agricultural practices can be identified in pollen records:

- Mixed farming where cereal-type pollen and other grasses are recorded along with other taxa associated with arable and pastoral activity.
- Possible cereal cultivation as part of a mixed economy, where cereal-type pollen is not recorded, but arable herbs are present.
- Non-specific agricultural activity reflecting vegetation disturbance along with arable and pastoral herbs .
-

Separating human impacts on vegetation from the influences of climatic variability or changing local conditions requires a burden of evidence resulting from multiple lines

of enquiry. A full range of palaeoecological indicators must be analysed, including the use of microscopic charcoal and minerogenic layers in sediments.

Microscopic Charcoal

The presence of microscopic charcoal in Holocene sedimentary records is an important indicator of past fire (Tolonen, 1986; Patterson *et al.*, 1987). Evidence provided by charcoal is crucial to understanding patterns and processes in natural vegetation changes (Clark et al, 1996; Pitkanen et al, 1999; MacDonald et al, 1991) and those induced by human activity (Clark and Royall, 1995; Bennett, et al, 1990). Microscopic charcoal studies in Britain have mainly investigated the potential links between human activity, climate change and fire frequency during the Mesolithic (Tipping, 1996; Tipping & Milburn, 2000; Simmons & Innes, 1996; 2000; Edwards, 1993), but more recently, focus has turned towards understanding later Holocene fire ecology (*eg.*, Edwards & Whittington, 2000; Edwards *et al*, 1995).

The origin of charred particles in sediments is inferred from multiple sources of evidence which can include archaeological evidence for occupation, extensive vegetation changes, such as forest decline and the appearance of agricultural "indicator" species (Behre, 1981). Early interpretations were limited by a need for empirical data concerning these factors. Complications also arise from the various methods used to record and analyse data and the lack of standard procedures impedes comparison of results (Tipping, 1996). Increasing research has addressed issues of charcoal production, dispersal and deposition in a variety of environments and conditions (Blackford *et al.* 2000; Scott, *et al* 2000; Clark *et al*, 1998; Gardner & Whitlock, 2001; Ohlson & Tryterud, 2000) although data collection and handling remains largely varied. This section will discuss the factors which influence the formation of microcharcoal records in sediments and focus on an assessment of the ways in which this research improved the ability to understand and interpret past fire activity.

The most basic assumption in the interpretation of microcharcoal is that "large" particles represent the occurrence of local fires (Tolonen, 1986; Clark & Royall, 1995; Patterson et al, 1987). Clark (1987) maintained that pollen-slide charcoal, <50 μm would be of low spatial and temporal resolution and that particles >125 μm represent

primary sedimentation processes. This appears to be supported by a study of a present day heathland burn (Blackford, 2000). However, Clark conceded that both Backman (1984) and Anderson *et al* (1984) were able to show the occurrence of local fires from pollen-slide charcoal, but stresses that this is dependent on large particles surviving the pollen extraction process. Clark & Hussey (1996) also showed that particle shape is a factor in transport, as elongate particles will tend to travel shorter distances.

In further contrast to Clark's (1988) model, Pitkanen *et al.* (1999) found that pollen slide charcoal was a good indicator of local fires, but noted that uncertainty remains as to whether it is an adequate recorder of all local fires, or limited to the low intensity type burns found in their study area. Blackford's (2000) study provided a crude estimation of background charcoal in sediments, suggesting that 66-82% of total charcoal <20 μm and 0-2% >125 μm should typically represent a regional or larger source area.

Peat bogs can produce *in situ* charcoal (eg., burning of heath for grazing), and there is a high probability that a proportion of "old" charcoal will be consumed by subsequent fires, eradicating or distorting the cumulative record (Patterson *et al*, 1987; Pitkanen et al., 1999) This will be affected by the frequency, location, intensity and type of fire. Although experimental work by Ohlson and Tryterud (2000) on forest soils and Blackford (2000) on dry heathland confirmed that older charcoal is destroyed, there is no available research which attempts to quantify how much charcoal might be consumed.

The burning of low vegetation such as heather, herbs and grasses tends to produce correspondingly 'low' fires. The limited convection of this type of fire reduces the amount of microcharcoal lofted to heights where it could be transported great distances, and most of the microcharcoal produced tends to be deposited locally. High intensity crown fires, characteristic of coniferous forests, tend to disperse charcoal greater distances (Bennett *et al.*, 1990) It is thought that the deciduous forests of later Holocene Britain would not have been susceptible to fire from natural causes (Rackham, 1980). However, under certain conditions, for example, during drier

summer months, upland heaths may sometimes be vulnerable to fires caused by lightning strikes and in the northern Scottish native pinewoods, fires are believed to be an essential part of the regeneration process (McVean & Ratcliffe, 1962). Careful analysis of particle size data and comparison with pollen concentration data may assist in inferring whether the sources of the microcharcoal were likely to have been local or regional (Sarmaja-Korjonen, 1992). Recent work (Dark, 1998; Gardner & Whitlock, 2001) has shown the potential for identifying the source material of charcoal, but no attempt was made to identify the charcoal in this study because of the ambiguous nature of the results from current work.

Experimental work has shown pollen-slide charcoal, measuring between 50 and several hundred microns, to be an adequate indicator of local fires or of those located within a few kilometres of the sampling site. Because of the composite nature of charcoal assemblages and the complex taphonomic processes discussed above, abundance of microcharcoal can be used as an estimate of overall fire activity at a given time (Sarmaja-Korjonen, 1991; Innes & Simmons, 2000). Use of size classes is likely to provide a rough estimate of source area (Pitkanen & Huttunen, 1996), but determining the precise frequency, spatial extent and intensity of palaeofires remains, for the time being, impractical. However, the incorporation of microscopic charcoal analysis into palaeoecological studies adds an additional valuable perspective on past vegetation change and human activity.

Minerogenic Layers

The presence of minerogenic layers in peat sediments are interpreted as evidence of landscape instability, resulting from climate change or anthropogenic influence (Smith & Hirons, 1986). Despite the apparent coincidences in timing between landscape changes and erosional activity in upland Britain during the later Holocene, causal relationships should not be assumed and effort should be made to design studies which can effectively link erosion with land-use of climate change using the palaeoenvironmental record (Ballyntyne, 1991). A comprehensive discussion of the history of the recognition of minerogenic materials in peats and their potential usefulness in palaeoenvironmental reconstruction also highlights that pollen analysis has provided evidence that the presence of minerogenic layers can be attributed to palaeoenvironmental changes initiated by humans (Edwards, *et al.* 1991). It has been

suggested that mineral layers in peats can be a good indicator of arable activity (Vuorela, 1983) when taking into consideration pollen and charcoal data. The use of loss-on-ignition when considered critically against other evidence of human impacts, such as evidence of arable activity of high grazing pressure, can be useful in reconstructing the nature of past human activity.

Peat Bogs as Proxy Indicators of Climate Change

Palaeohydrological changes in mire systems have been inferred using a number of different methods. As noted above, plant macrofossils have been shown to be a reliable indicator in ombrotrophic peats (*eg.* Barber *et al.*, 1994). In blanket and basin peats, changes in mires surface wetness have been inferred by measuring the degree of peat humfication, because of the unavailability of examining plant macrofossils. As Charman (2001) recently noted the advantage of measuring peat humification by colormetric methods is its relative ease and efficiency compared to other techniques such as macrofossil analysis. It is also more widely applicable to a number of different peat types and it facilitates the construction of high temporal resolution proxy climate reconstructions.

The use of peat bogs as proxy climate archives hinges on several key assumptions (after Blackford, 2000):

- The water table responds to changes in precipitation.
- Changes in mire surface taxa are a function of changes in the water table.
- Pollen assemblages and other fossil indicators can provide accurate reconstructions of past mire surface communities.
- Drier surface conditions are represented by the formation of dark coloured sediments with very few fossil plant remains and relatively high proportions of humic acids; wetter conditions are indicated by lighter coloured peat and poorly decomposed organic materials.
- Reliable age estimates can be obtained from peat profiles.

On the mire surface, the decay of plants after death takes place for the most part in the oxygenated layer of peat above the watertable called the 'acrotelm'(Malmer, 1982).

Gradually, the decaying organic material is deposited in an anaerobic layer below the water table called the 'catotelm'. Once deposited in this layer, decay becomes very slow, perhaps by as much as 100 times, although not ceasing altogether (Malmer, 1992). As the position of the water table changes seasonally, the boundary between the acrotelm and catotelm is defined by the lowest depth reached by the water table during the summer (Clymo, 1984).

The theory behind studying the degree of peat humification is that it reflects changes in the amount of time taken between the death and decay of a plant on the mire surface and its deposition in acrotelm (Blackford, 2000). When mire surface conditions are drier, the exposure of organic matter to micro-organisms is increased. The prolonged breakdown of the organic matter results in the amorphous structure of the sediment and also causes the release of 'humic' substances, which give well humified peat sediments their characteristic dark colour. Humic acids occur in some proportion all soils and in peats they may comprise up to 100% of the soil organic matter, or SOM, but are more often comprised of a mixture of humic, humin and fulvic acids. If there is a rise in the water table, the anaerobic, waterlogged conditions reduce the exposure of organic matter, hence preserving plant material and inhibiting the release of humic substances, resulting in generally lighter coloured sediments.

Measuring the Degree of Peat Humification

The degree of peat humification is commonly assessed by a method of colorimetry which measures the concentrations of humic acids in the sediment (Blackford & Chambers, 1993). Humic acids are extracted by digesting the sediment in sodium hydroxide (NaOH) and the resultant solution is measured using a colorimeter. The complete laboratory procedure based on Blackford (1990) and modified by McCulloch (*unpub.*) can be found in Appendix IV. The results are expressed as the percentage of light transmitted through the solution relative to the standard, distilled water (Blackford, 1990). Low percentages of light transmission through very dark coloured solution indicate well decomposed peat, inferred to be formed under drier conditions. Lighter coloured solution with higher percentage transmission values reflects well preserved peat, inferred as wetter mire surface conditions.

Palaeoclimatic Inferences

The percentage light transmission values provide the foundation for inference of palaeohydrological changes at the three sites. However, building on the work of Tipping (1995a) multiple indicators of peat humification were derived from the pollen record. These include the evaluation of pollen preservation and concentrations in relation to percentage transmission data, as well as the interpretation of mire surface vegetation (*eg.*, Anderson, 1998; Chambers *et al.*, 1997; Moore, 1986; Tipping, 1995a; Wimble, 1986). However, as with many proxy indicators of palaeoenvironmental change, these indicators may be influenced by a number of different conditions and processes which need to be taken into account when interpreting potential causal factors and mechanisms.

Pollen preservation: Cushing (1967) and Havinga (1964, 1985) provided the foundations for much of the current understanding of the implications of pollen preservation to palaeoenvironmental reconstruction. Pollen grains are subject to a number of potentially damaging processes both before and after being deposited on the surface of a bog or lake. The type and extent of damage to pollen grains reflects the influence of local site conditions, the nature and origins of the sediment and the environmental history of the area (Lowe & Walker, 1986). Corrosion occurs to pollen grains when, like the plant matter growing in the mire surface, they are exposed to micro-organisms in aerobic conditions (Havinga, 1964, 1984). Lower water tables resulting in organic matter spending more time in the active catotelm would then be expected to result in the increased corrosion of pollen grains, with improved preservation during periods when the water table is raised.

In the course of being incorporated into the pollen assemblage, damage to grains can result from a number of processes. Syndepositional corrosion or degradation occurs more or less concurrently with the production and dispersal of the grains (Tipping, 1987). This can include mechanical damage caused by aeolian transport and corrosion in addition to prolonged exposure to aerobic conditions. Once the pollen is deposited in sediments, there is further potential for damage. Sediment compaction can cause crumpling and breakage. Mineral in-wash into peat sediments may carry with it pollen grains which may be mechanically damaged when transported to the site, re-exposure to air may also cause further corrosion and degradation.

Damage can be introduced by the pollen processing procedure as well. Grains which are exposed to acetolysis solution for too long may exhibit surface etching. Stirring the pollen pellet in between steps may result in the crumpling or breakage of pollen, particularly susceptible taxa include *Pinus* (Cushing, 1967). A vortex mixer was used for steps involving non-hazardous substances to minimise any damage caused by stirring.

Pollen Concentrations: Calculating pollen concentrations is helpful because they are, in effect, the result of sediment accumulation rates (Middledorp, 1982). Although pollen concentrations are to some extent reflective of the absolute abundance of pollen grains in the sediment, they are more strongly dependent on changes in sediment accumulation and compaction (Tipping, 1995a). Highly humified peats tend to be more compacted and have accumulated more slowly, resulting in a higher concentration of pollen grains. Sediment compaction may also lead to a higher proportion of mechanically damaged grains due to increased pressure on pollen grains (Tipping, 1995a).

Mire Surface Vegetation

The reconstruction of mire surface vegetation from fossil pollen assemblages is a line of evidence which also can be used to support inference about past mire hydrology (Moore, 1986). Applications of this method are varied and often contradictory. For example, Anderson (1998) used Cyperaceae as an indicator of mire surface wetness. However, Wiltshire and Moore (1983) suggest that Cyperaceae is not a good indicator of mire surface wetness because of the wide ranging conditions to which members of Cyperaceae are adapted. Cyperaceae are also highly sensitive to burning and grazing (*cf.* Huntley & Birks, 1983), and may respond to anthropogenic impacts more strongly than mire hydrology. Tipping (1995a) used the ratio of *Calluna:Sphagnum* as an indicator of mire surface wetness, on the basis that higher proportions of *Calluna* indicate relatively drier mire surface conditions (Ratcliffe, 1965), with equivocal results. n modern day vegetation surveys, wetter mire conditions are associated with abundant coverage of *Sphagnum* relative to *Calluna* (Gimingham *et al.*, 1983; Rodwell *et al.*, 1991b).

The difficulty at a palynological level with distinguishing wet heaths from dry heaths is the taxonomic imprecision with which members of Ericaceae, the family of *Calluna* and other heath plants, can be identified. For example, the dominance of *Erica tetralix* is generally indicative of wetter conditions than usually associated with the dominance of *Calluna* (Rodwell *et al.*, 1991b). However, it is generally difficult to separate *Erica tetralix* from other species such as *Erica cinerea.* Gimingham *et al.* (1983) note that on wet heaths the abundance of *Calluna* is generally limited to raised hummocks, surrounded by predominantly *Myrica gale*, *Sphagnum*, grasses and sedges. A further taxonomic difficulty presents itself with the inability to easily separate *Myrica gale* pollen from that of *Corylus avellana.* These are usually, as is the case in this investigation, treated as *Corylus/Mryica*-type in the counting process and in the pollen sum. I

Using ratios of *Calluna*:*Sphagnum* is also more appropriate to raised mires, as in these settings *Calluna* is typically confined to the mire. In upland landscapes such as the Strath of Kildonan, *Calluna* may be present in a number of environments and changes in its abundance may be contingent on processes not necessarily confined to mire hydrology. Which brings us to a final aspect which is commonly ignored is the potential human impact on mire surface vegetation: burning, cutting and grazing will all influence the relative abundance of vegetation types growing on the mire in different ways (Blackford, 1998). This investigation will take careful account of the mire surface vegetation assemblage as reflected in the pollen record. However, all pollen- and peat-stratigraphic data will be carefully assessed to determine more reliably the relationship between vegetation change, palaeohydrological shifts and human activity.

Chronology

Accelerator Mass Spectrometry (AMS) Radiocarbon Chronology

While the dating of palaeoenvironmental profiles generally presents fewer problems associated with provenance and taphonomy, the technique still suffers from the same experimental and systemic errors associated with the dating of organic material in archaeological contexts. Palaeoenvironmental samples are also vulnerable to contamination during the coring process, although the use of a closed- chamber

Russian corer limits this, and when samples are being extracted for dating. There is also an issue that the different components which make up the SOM in peat, humic, humin and fulvic acids will reflect different ages. For example, fulvic acid is highly soluble and is therefore extremely mobile in the sediment, making it an unsuitable fraction for dating. The compromise that has arisen between the ideal approach of dating the pollen grains themselves and a 'bulk' sample of pollen, vegetation and the humin/humic fractions of the peat is dating the fine particulate matter in peat by sieving out rootlets and vegetation (Pilcher, 1993). Of the three components of SOM humics are the least soluble, and therefore the least mobile substances in the peat and can provide a more reliable radiocarbon age determination than humin and fulvic acids (Bowman, 1990).

In order to reconstruct changes as close to a human temporal scale as possible, it was necessary to obtain dates of the highest possible resolution. Eight Accelerator Mass Spectrometer (AMS) dates were provided for KLD by the Natural Environment Research Council's (NERC) Radiocarbon Steering Committee (Grant No.909.0501). Six AMS dates for Loch Ascaig and four from Kinbrace Hill were obtained from the Scottish Universities Environmental Research Centre (SUERC) with funding from the Moray Foundation, University of Edinburgh. Samples of 1.0 cm thickness were carefully removed after cleaning away the surface and edges of the core to avoid contamination by potentially younger material. These were transferred into glass sample tubes and wrapped in foil. Samples were prepared by technicians at the NERC Radiocarbon Laboratory in East Kilbride, Scotland (Appendix 4).

Dating control also remains an important issue in the correlation of mire stratigraphies from different sites (Blackford, 1998). Incorrect or unreliable dates are often difficult to detect except in rare cases where closely spaced dates are available (Dumayne *et al.*, 1995) and the accuracy and reliability of quoted errors on radiocarbon dates is often unknown (Pilcher, 1991). Although the latter is a problem in a wide range of circumstances. Wiggle-match dating (Kilian *et al.*, 1995) offers a potential solution, but obtaining the necessary multiple dates can be prohibitively expensive.

Tephrochronology

Recent work has shown the potential for the correlation of proxy climate records using tephrochronology (Chambers, *et al.*, 1997; Dugmore, 1989). Tephra layers can assist in constraining the radiocarbon chronology as fixed reference points in the profile, as well as providing a continuous dating horizon across wide geographic areas (see below). Tephras may also assist in correlating horizons of interest in palaeoenvironmental records where radiocarbon age determinations fall into plateaux. Tephra is defined as any pyroclastic fallout from a volcanic eruption. In most tephrochronological contexts, the term normally refers to discrete layers of ash visible to the naked eye and forming detailed stratigraphies. Ash layers which can be attributed to specific eruptions and which form a continuous event surface across hundreds or even thousands of kilometres allow more temporally precise correlations than can be achieved by radiometric dating alone. Multiple age estimations obtained for tephra layers make them a more accurate tool for cross correlation of environmental profiles than biostratigraphic horizons (*e.g.*, the pine decline) or individual radiocarbon dates (Newnham *et al.*, 1997).

The most fundamental assumption of tephrochronology is that the mineralogical properties of a tephra are consistent throughout its distribution (Hodder, *et al.*, 1991). However, it is recognised that there are several processes which can alter the relative abundances of minerals. Aeolian fractionation occurs because high density minerals settle quickly and tephras transported long distances are depleted of these minerals. Hodder *et al.*(1991) have shown that the ferromagnesian component of basic tephras can be altered in environments where pH <4. In order to assess the potential influence of these and other factors on the development of Scottish and Icelandic tephrochronologies, Dugmore *et al.* (1992) undertook a comparative study on tephras from Iceland and Scotland from both peat bogs and more minerogenic environments. Their results showed that the geochemistry of the glass shard component of a tephra does not vary with distance from the source and that the geochemical fingerprint of any given tephra is consistent spatially and temporally, without regard to the depositional environment.

The tephrochronology constructed for the Strath of Kildonan is derived from layers which are more accurately described as "microtephras". The shards form discrete layers in the peat, but are invisible to the human eye with shard size varying from

*c.*25μm to 100μm. The first microscopic tephra layers in Britain were discovered at Altnabreac, in The Flow Country, Caithness (Dugmore, 1989). Major element analysis revealed that the shards extracted from the Altnabreac profile were geochemically similar to the Hekla 4 tephra, already dated in Iceland to about 4,000 ^{14}C years BP (Larsen & Thorarinsson, 1977). Since then several more tephra layers have been revealed in British and Irish peats, creating a tephrochronology for the British Isles stretching back to 10,300 ^{14}C years BP (Turney, et al, 1997) (Table 5.2.).

Table 5.2 Scottish tephra horizons . After Dugmore *et al.* (1995)

Tephra	Age in ^{14}C years	Calibrated ^{14}C/Calendar
H 1510*		AD 1510
Loch Portain	*ca.* 450 BP	288-516 cal BP
		502-644 cal BP
Glen Garry	*ca.* 2100 BP	1827-2111 cal BP
		1940-2309 cal BP
		2006-4072 cal BP
Kebister	*ca.* 3600 BP	3742-4072 cal BP
Hekla 4	*ca.* 3830 BP	4150-4271 cal BP
Hoy tephra	*ca.* 5600 BP	6177-6555 cal BP
Lairg A & B	*ca.* 6000 BP	6600-7200 cal BP

*Dated from documentary sources.

Handling and Presentation of Data

Pollen Analysis

Initial sub-sampling of 1.0 cm^3 sediment slices for pollen analysis was at 8.0 cm intervals to locate key pollen-stratigraphic horizons, and then as fine as 1.0 cm intervals to focus on later Holocene human impacts. Samples for pollen analysis were prepared following standard techniques (Moore *et al.*, 1991) which are detailed in Appendix IV. Pollen samples were counted on an Olympus BX-40 microscope at 400x magnification to sums of at least 500 grains of land pollen for most levels. For levels with particularly poor pollen preservation or very low concentrations outside the depths of interest, pollen sums of 300 were counted for the Kinbrace Hill profile. 1000x magnification was used to facilitate identification of rare pollen types.

Data Presentation and Zonation of Pollen Diagrams

Pollen and microscopic charcoal data from the three profiles was stored, analysed and presented using TILIA and TILIA-GRAPH (Grimm, 1991). Data is presented for the profiles as relative pollen percentages of each taxon, pollen concentrations, pollen preservation and relative percentages of microscopic charcoal size classses. Pollen zonation describes the process of breaking down the pollen diagrams into smaller, more manageable segments to facilitate the description, discussion, comparison, interpretation and correlation (spatial and temporal) of the pollen data (Birks & Gordon, 1985). The pollen zone is a somewhat fluid concept, but it is, *sensu stricto*, a biostratigraphic unit constructed on the grounds of pollen content alone (Moore, *et al.*, 1991). Local pollen assemblage zones (lpaz) were constructed for each core using by the application of generalised Euclidian distances using CONISS (Grimm, 1987), a stratigraphically constrained clustering programme in TILIA. Zonations were based on major land pollen taxa which consistently achieved values greater than 5%tlp. To avoid any incorrect generalisations, comparisons of this technique with others showed the results of the zonation to be robust. Zonations are applied to all subsequent pollen- and peat- stratigraphic data sets.

Construction of the Pollen Sum

The pollen percentage diagrams for each profile were constructed using a pollen sum based on total land pollen (tlp), excluding Cyperaceae, aquatics and spores (Moore *et al.*, 1991). In the Strath of Kildonan and other sites in northern Scotland, *Calluna vulgaris*, heather, is found growing on the sampling site as well as the surrounding dryland. This is unlike raised bog sites from southern Scotland and England, where *Calluna* is only found on the bog itself. In these cases, *Calluna* is excluded from the total land pollen (tlp) sum, but in this investigation it is included in the tlp sum in recognition of its significance in the landscape as a whole. The major drawback with relative data sets such as this is that the proportions are dependent; a change in the representation on type of pollen will alter the proportions of other types, even if there is no absolute change in the amount of pollen from the other types entering the site.

Pollen Concentrations

Pollen concentration is the number of grains per unit volume of wet sediment and is expressed as grains cm^{-3}. Unlike pollen percentages, they are independent; a change

in the concentration value of one taxon does not necessarily produce relative responses in others. In order to mitigate the difficulties presented by using proportional data such as the pollen sum discussed above, pollen concentrations are useful as an absolute measure of the pollen grains deposited in a volume of sediment. Tablets containing a known quantity of exotic 'marker spores' (Stockmarr, 1971) were added to each sample to allow the construction of pollen and charcoal concentration curves. Pollen concentration curves were constructed for the major taxa in the land pollen sum.

Pollen Preservation

As discussed above, pollen preservation is an important indicator of the depositional environment of pollen grains. The pollen preservation categories used here are after Cushing (1967):

- **Normal.** No indications of chemical or mechanical damage.
- **Corroded.** Indicates the presence of biological activity. The exine of the pollen grain may be pitted, scored, etched or perforated.
- **Degraded.** Thinning of the exine indicating chemical oxidation in aerial or sub-aerial conditions.
- **Crumpled/Broken.** Mechanical damage can be caused during transport of the grain or by subsequent sediment compaction after deposition. "Broken" indicates the rupturing of the exine and "crumpled" grains are badly folded, wrinkled or collapsed.

Grains which were too damaged to be recognised or were obscured by organic material which survived the pollen extraction process were categorised as 'unidentifiable'. Any grains whose characteristic features were indiscernible were included under the category 'unidentifiable'. Individual grains were assigned to categories based on the most conspicuous type of deterioration (Lowe, 1982). Data are calculated as the proportion of damaged grains of a particular taxon as a percentage of all damaged grains. Some taxa, for example, *Corylus avellana*-type are particular susceptible to corrosion and *Pinus sylvestris* to crumpling and breaking.

Presenting the data by this method reduces, but does not entirely eliminate, possible biases introduced by taxon specific susceptibilities.

Microscopic Charcoal and Charcoal Size Classes

Only black, opaque, angular particles >20 μm were counted because of the uncertainty in correctly identifying charcoal fragments of such small size. Charcoal particles were categorised into five classes based on length measurements (Tipping, 1996; Tipping & Bunting, *unpub*): 20-30 μm, 30-40 μm, 40-50 μm, 60-70 μm and >70 μm. Fragments measuring >70 μm were also recorded individually. Based on the results of Blackford (2001), Clark (1987) and Tipping (1995c), majority proportions of charcoal particles 50 μm and larger are interpreted as indicative of local burning. The classes are presented as percentages of the total charcoal sum.

Humification Data

The degree of peat humification in this study was measured following the methods of Blackford (1990) and Blackford Chambers (1993), adapted by McCulloch (*unpub*). Other palaeoclimate reconstructions in northern Scotland (Davies, 1999; Dixon, 1994; Anderson, 1998; Charman, 1997) have used Blackford & Chamber's method of analysis, and it is crucial that the results of this investigation are comparable with previous work. The results of the colorimetric analyses of the peat sediments are presented as percentage light transmission. The data were corrected for mineral content using the equation: percent organic matter/100 x percentage transmission (Blackford, 1990).

Loss-on-ignition Data

The percentage of organic matter in the sediments was determined using loss-on-ignition (LOI) (Appendix IV). Organic material is combusted in a furnace, leaving the residue of mineral material behind. This is considered the most reliable technique of determining what proportion of the sediment is composed of organic matter (Heiri, *et al*, 2001). Loss-on-ignition data are presented as percent organic matter.

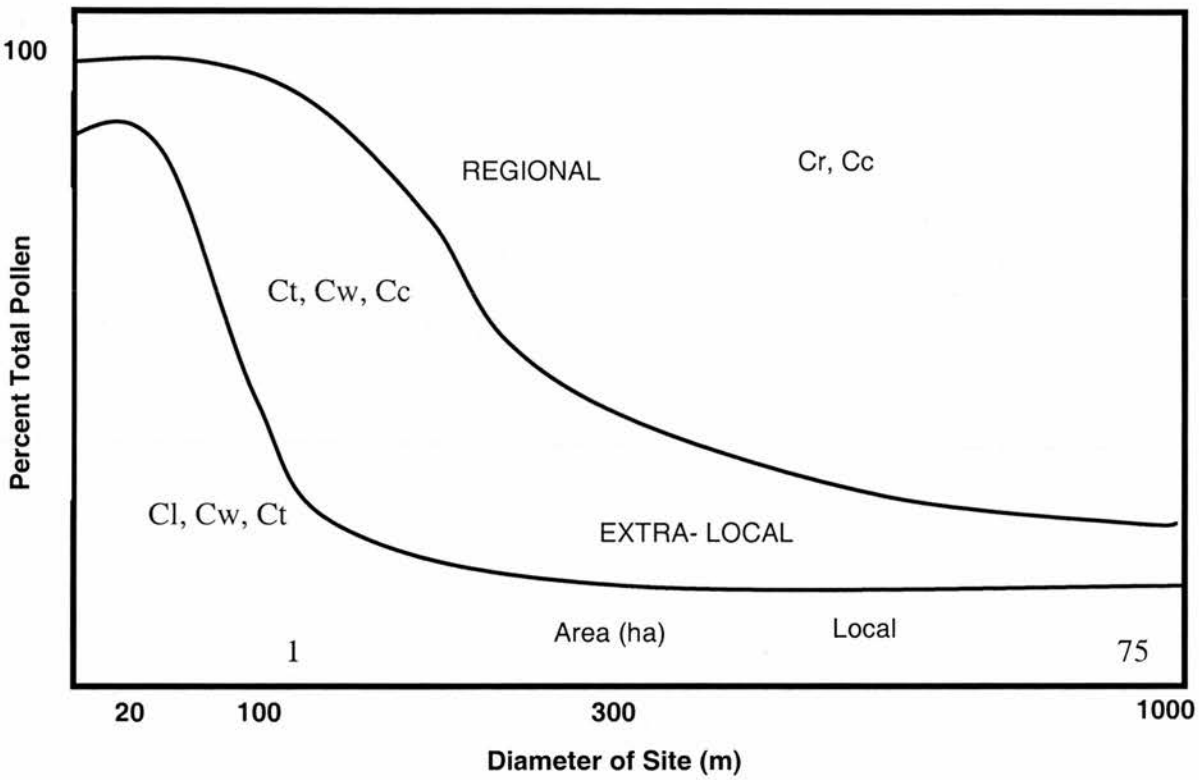
Analytical Data and Diagnostic Characteristics of Tephra Layers

Samples were prepared by acid digestion (Dugmore *et al* 1992; Appendix IV) and analysed geochemically at the Natural Environment Research Council electron

microprobe facility, Department of Geology, University of Edinburgh. The collected geochemical data was compared using ternary plots based on relative weight percentages of total iron oxides, potassium oxide and calcium oxide (*cf.* Dugmore *et al.*, 1995) . Although cluster analysis and discriminant functions can be employed in situations where data correlation is problematic, the simpler method used here is considered appropriate for most types of data, including that presented here (*cf.* Froggatt, 1992). The major element comparisons of the tephras from Loch Ascaig, Kinbrace Hill and Kildonan Lodge exhibit enough variation to be easily differentiated using these simpler techniques, and previous work has established their efficacy (*cf.* Dugmore, 1989; Dugmore *et al.*, 1995; Mangerud *et al.*, 1984; Jakobsson, 1979). Identifications were made by comparing geochemical data from the Strath of Kildonan tephras with geochemical data from known tephra horizons stored in *Tephrabase* (Newton, 2003). Geochemical data is presented in tabular form in Appendix V.

Conclusions

This chapter has provided key information about the methods used to test the hypothesis of a Later Bronze Age catastrophe in the Strath of Kildonan by choosing sensitive sites and employing methods which can extract both climate and human impact signals. Pollen data will provide information about both mire surface vegetation related to palaeohydrological changes, as well as human impacts in the surrounding dryland vegetation. Other techniques such as loss-on-ignition and microscopic charcoal will also help to evaluate human impacts on the natural environment and other activities. The degree of peat humification, as well as other indicators such as pollen preservation and concentrations, are used to reconstruct palaeohydrological changes in the mires and infer past climate change. The combination of data collection and analysis techniques introduced here provides a rigorous and systematic means of interpreting environmental changes and human impacts. These records of past change and activity are placed in context by constructing a reliable chronology based on radiocarbon dating and tephrochronology.



Cc=canopy component, Cl=local component, Cr=rain out component, Ct=trunk space component, Cw=secondary component transported by water

Figure 5.1. Estimated pollen recruitment areas based on the diameter of a sampling site in a forested landscape. Re-drawn from Jacobson & Bradshaw (1981)

Level I. Settlement and environmental variables.
This level of analysis describes the geographical setting and environmental characteristics of each settlement site.

Level 2. Site and catchment.
A single unit of subsistence activity. The extent of the exploitation area of the settlement is probably not clear from the archaeological record alone. Careful selection of methods and sites for palaeoenvironmental reconstruction can assist in identifying the range and extent of subsistence activities through time.

Level 3. **Inter-site variability in a regional** context.
Archaeological chronologies are probably imprecise and it is difficult to assess which sites would have been occupied concurrently. Comparison of palaeoenvironmental reconstructions between sites may reveal variations in agricultural subsistence patterns, timing and rates of vegetation change and site occupation.

Level 4. Systems of extra-regional contact.
Evidence of trade may be apparent in the archaeological record, although there may be no way of knowing how extensive and formalised links were. Riverways and other natural features may indicate possible routes of exchange.

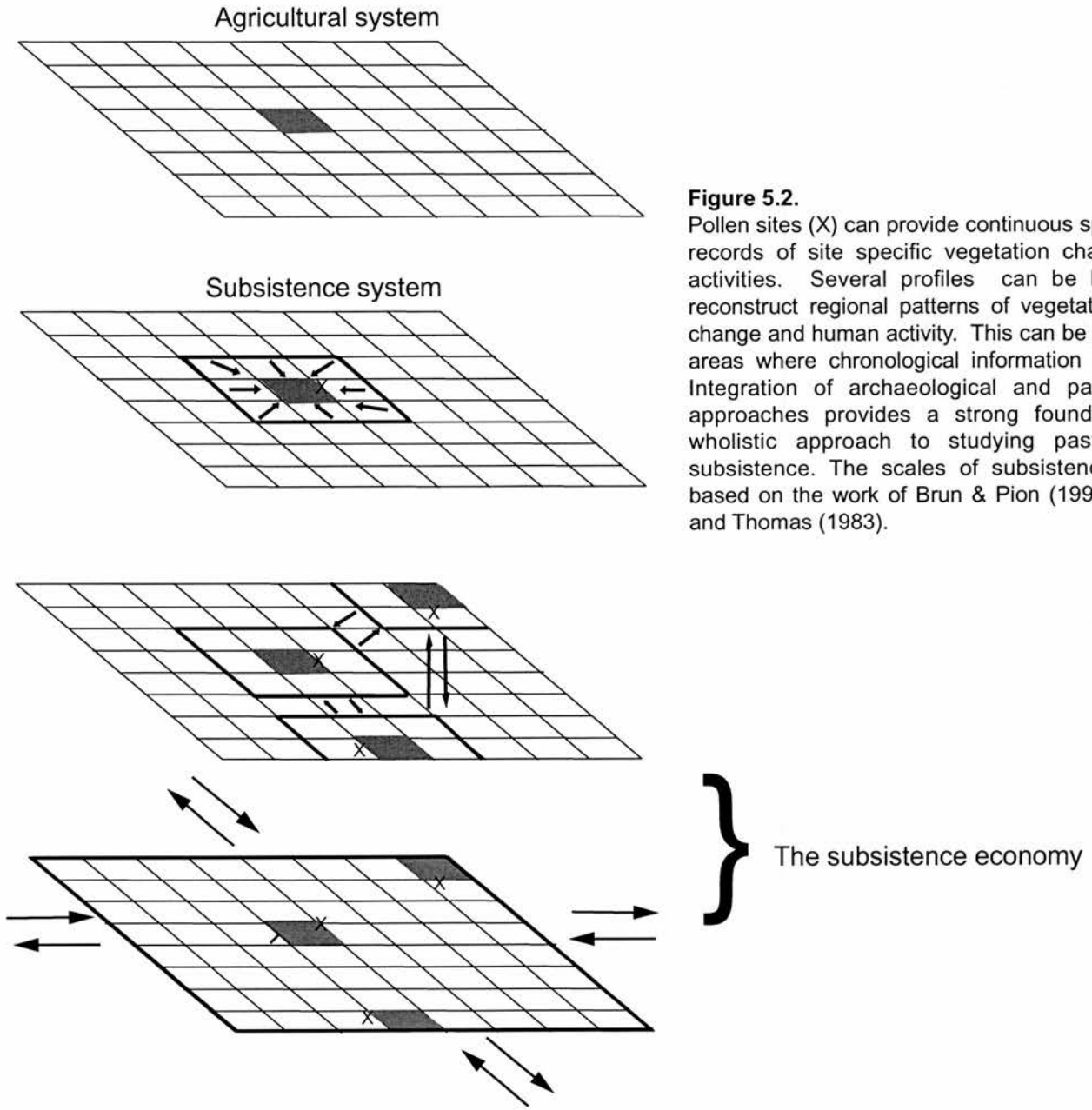


Figure 5.2.
Pollen sites (X) can provide continuous spatial and temporal records of site specific vegetation changes and human activities. Several profiles can be linked together to reconstruct regional patterns of vegetation, envrionmental change and human activity. This can be especially useful in areas where chronological information is poor or limited. Integration of archaeological and palaeoenvironmental approaches provides a strong foundation for a more wholistic approach to studying past settlement and subsistence. The scales of subsistence used here are based on the work of Brun & Pion (1992), Fleming (1988) and Thomas (1983).



The Upland Plateau:
Managed heathland for grouse shooting and deer hunting.

'Greenlands':
Prime arable and pasture land.

'Blacklands':
Peatlands. Poorer ground used for grazing and the cutting of peat for fuel.

Figure 5.3. 'Marginal' Environments. View of the Strath of Kildonan looking north from the Kildonan Lodge site. The 'greenlands' in the middle distance, the 'blacklands' in the foreground and the upland plateau in the background comprise a gradient of increasing marginality in relation to later prehistoric settlement in the Strath.How does our perception of these modern day environments inform our understanding of the past?



Figure 5.6. Kinbrace Hill



Figure 5.5. Loch Ascaig.



Figure 5.4. Kildonan Lodge.

Marginality



Figure 5.7. Kildonan Lodge. Estimated source area after Jacobson & Bradshaw (1981) and additicnal archaeology data RCAHMS (1993).

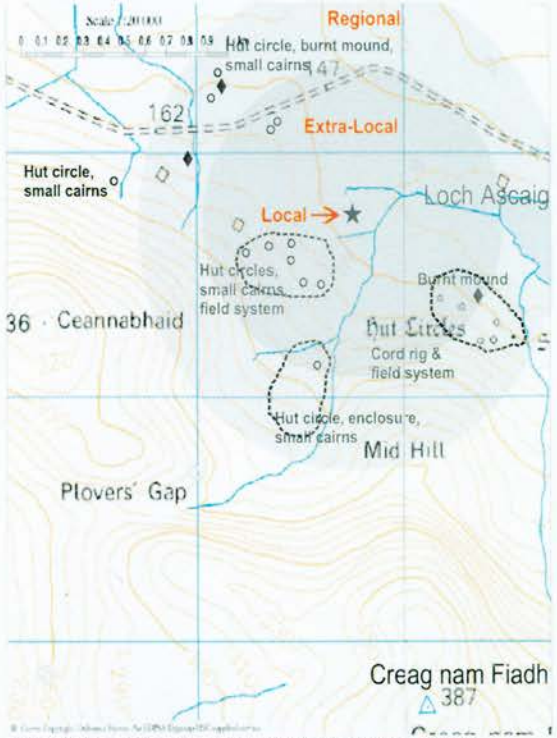


Figure 5.8. Loch Ascaig.. Estimated source area after Jacobson & Bradshaw (1981) and additional archaeology data RCAHMS (1993).

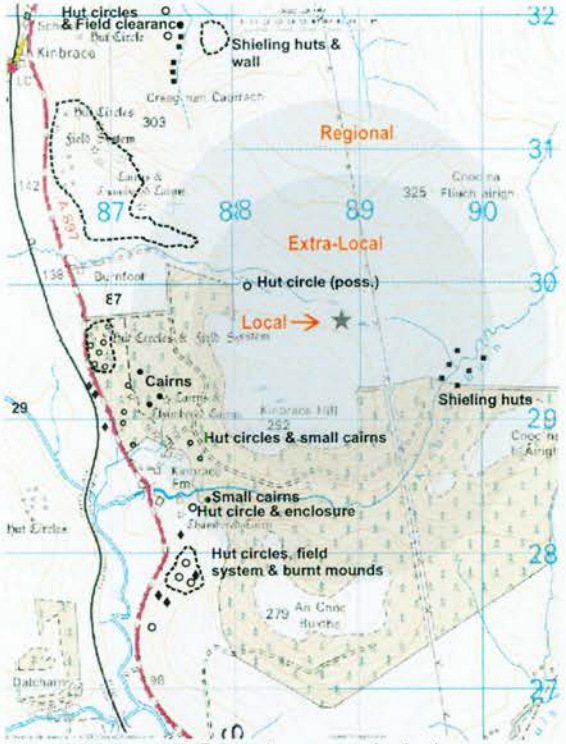


Figure 5.9. Kinbrace Hill. Estimated source area after Jacobson & Bradshaw (1981) and additional archaeology data RCAHMS (1993).

Chapter 6

Loch Ascaig

This chapter presents the pollen- and peat-stratigraphic analyses for Loch Ascaig. The Late Holocene sequence analysed here begins at 370.0cm. This site was chosen for investigation because of the relative density of Group 1 and 2 settlements, which are thought to reflect more marginal and intermittent settlement (*cf.* Cowley, 1998; RCAHMS, 1993) (Figure 4.2, 5.8). The archaeological evidence from survey (RCAHMS, 1993) is summarised in Appendix I.

Chronology

Six AMS dates were obtained for the profile and are summarise in Table 6.1. Figure 6.1 shows the calibrated 2σ age ranges plotted against depth. Figure 6.2 shows the 2σ calibrated BC/AD age ranges. Chronology of the profile was further constrained by the Hekla 4 tephra at 354.0cm and the Glen Garry tephra at 293.0cm. Geochemical data for these two tephra horizons is presented in Figures 6.3 and 6.4 (see also Appendix V). Linear accumulation rates were assumed between each AMS date and/or tephra horizon. Ages of significant changes not directly dated by AMS dates or tephra horizons were interpolated using estimated sedimentation rates between dated horizons.

Publication Code	Sample Identifier	Conventional Radiocarbon Age	$\delta^{13}C_{PDB}$ ‰ ± 0.1	Cal BP 2σ	Cal BC/AD 2σ
AA-51412	LAS 1 330.0cm	3490±40	-28.1	3850-3680	1900-1730 BC
AA-51413	LAS 2 316.0cm	2870±40	-27.6	3080-2870	1130-920 BC
AA-51414	LAS 3 304.0cm	2314±40	-28.2	2365-2300	415-350 BC
AA-51415	LAS 4 276.0cm	2010±45	-28.1	2065-1870	120 BC-AD 80

AA-51416	LAS 5 214.0cm	1540±40	-28.6	1520-1320	AD 430-600
AA-51417	LAS 6 164.0cm	1270±40	-27.4	1285-1165	AD 665-785

Peat- and pollen-stratigraphic data

Pollen percentage, concentration, microscopic charcoal and pollen preservation data are presented in Figures 6.5, 6.6, 6.7 and 6.8. Humification data are presented in Figures 6.9a and b. Loss-on-ignition data are presented in 6.10. Descriptions of the core stratigraphy are appended to the Figures 6.9 and 6.10.

Lpaz LAS 1a
370.0-353.0cm
Betula-Pinus-Calluna-Poaceae
***ca.* ?4,450-4,210 to ,4360-4,090 cal BP**
***ca.* ?2500-2290 to 2410-2140 cal BC**

The Holocene Woodland around Loch Ascaig *ca.* ?4,450-4,210 cal BP*

The late Holocene woodland around Loch Ascaig, whilst dominated by *Betula* and *Pinus* as indicated by pollen percentages (Figure 6.5; *cf.* Huntley & Birks, 1983), was a diverse and species-rich environment. *Betula* was joined by other broad-leaved deciduous tree and shrub taxa including *Alnus*, *Corylus/Myrica, Populus, Quercus, Salix, Sorbus* and possibly *Ulmus*. Evergreen shrubs included *Juniperus* and a variety of ericaceous taxa, including *Calluna*. The species composition of the woodland and other vegetation communities would have varied on range of spatial scales depending on local edaphic conditions.

Pinus prefers relatively infertile, and often sandy soils, but can also be found on thinner, drier peats (McVean & Ratcliffe, 1962). It probably competed well with *Betula* on the better, drained acidic soils. It may also have been established on the drier margins of the mire itself (*cf.* Birks, 1975). Occasionally *Pinus* can be found on more saturated peats, but here it grows poorly and does not live as long (McVean, 1964). *Betula*, on the other hand, exhibits little preference in the habitats it colonises

*.Estimated ages for LAS 1a were extrapolated based on the calculated peat accumulation rate between the Hekla 4 horizon and the first AMS date at 330.0cm. The stated age ranges are inherently imprecise and correlations with archaeological and other palaeoenvironmental data are undertaken advisedly.

(Rackham, 1980) and may have been growing in a variety of places. It will tolerate a certain degree of intermittent waterlogging, and is, therefore, found on both wet and dry peats. In upland areas, the margins between broadleaved *Betula* woodland and coniferous woodland can often be blurred (*cf.* Peterken, 1996). Individual *Sorbus* trees may have been found scattered through the *Betula-Pinus* woodland (McVean & Ratcliffe, 1962). Generally, though, with rising altitude *Betula* would have formed increasingly mono-dominant stands in the rugged topography of the Srath na Frithe (McVean & Ratcliffe, 1962).

Large unidentified wood macrofossils were recorded in the sediments between 370.0 cm and 364.0 cm. This probably reflects the former growth of trees growing on or at the mire edge. The mire edge woodland may have formed something resembling a 'lagg' community of an open canopy of *Betula, Salix*, an occasional *Pinus*, *Calluna* and herbs such as *Anemone nemorosa, Primula vulgaris, Vicia-type, Viola* and Cyperaceae (*cf.* Birks, 1975). The mire surface may have been dry enough to allow the colonisation of *Betula,* forming an open woodland, with the shade-intolerant *Calluna* as the dominant understorey shrub (*cf.* Pennington, 1972).

The presence of *Corylus/Myrica*, here assumed to be *Corylus avellana*, indicates the presence of better drained, less acid habitats in the catchment (*cf.* Pennington, *et al*, 1972; Peterken, 1996; Savill, 1991). Its modest representation, <20%tlp (Figure 6.5), might indicate that it was probably growing as an understorey shrub in the *Betula* woodland (*cf*, Rackham, 1980), although in the more open forests characteristic of northern Scotland, it can often form an important component of the canopy (*cf.* Huntley & Birks, 1983). There are rare records of *Ulmus*, although this entomophilous taxa is typically under represented. Nutrient demanding, *Ulmus* would have preferred moist fertile soils such as any brown forest soils or pockets of glacial drift in the catchment (*cf.* Huntley & Birks, 1983). *Quercus* percentages ≤2% indicate either long distance transport, or the presence of scattered individuals on the better drained, acidic soils in the catchment (*cf.* Peglar, 1979).

On wetter soils, *Alnus*, joined by *Populus* and *Salix*, competed successfully with *Betula*. The field layer of the wet *Alnus* woodland included some Cyperaceae and *Equisetum* as well as herbs such as *Hypericum eloides, Saxifraga stellaris* and *Viola*

palsutris. Principle areas of *Alnus* woodland may have included the banks of the Allt Ceann a'Bheith and the shores of Loch Ascaig, areas where a sufficiently high water table would have been maintained. *Alnus* will also take advantage of moist hollows in woodland or open areas such as grassland (Huntley & Birks, 1983). Although a colonising taxa, *Alnus* does not compete well with other taxa and usually requires some disturbance to gain an advantage. *Alnus* also does not easily invade grassland in the absence of disturbance (Savill, 1991).

The Mire and Catchment Palaeohydrology

From *ca.* 4,450-4,240 cal BP, *Calluna* was an important part of the landscape, as indicated by pollen percentages. In northern Scotland, unlike other areas of Britain, *Calluna vulgaris* is not restricted to mires, but is an significant component of many other vegetation communities. *Calluna* would have formed a principle part of the understorey of the *Pinus* woodland (McVean & Ratcliffe, 1962). Together with *Pteridium*, it would have invaded gaps in the dry woodland canopy. It is difficult to distinguish between different types of heathland on palynological grounds (*cf.* Huntley & Birks, 1983), but the mire surface from *ca.* 4,450 cal BP was in all likelihood a mosaic of communities: areas of wet heath, characterised by *Sphagnum* (*cf.* McVean & Ratcliffe, 1962), dry heath with *Calluna* as the dominant ericaceous species (*cf.* Gimingham *et al.*, 1983), open *Betula* woodland with *Calluna* (*cf.* Huntley & Birks, 1983) and blanket mire communities, as indicated by the presence of *Narthecium ossifragium* (*cf.* O'Connell, 1998) may have been confined to the centre of the mire or other deeper, wetter areas of peat (*cf.* Rodwell *et al.*, 1991c). However, combined percentages of *Calluna*, *Sphagnum* and Cyperaceae do not reach the high values, *ca.* 60% or more, considered indicative of blanket peat dominated landscapes in LAS 1a (*cf.* Fossitt, 1994a).

Both Cyperaceae and *Sphagnum* are poorly represented prior to 364.0 cm (Figure 6.5). Their increased abundance after this may be a product of the reduction in tree cover, allowing their pollen to travel more freely (*cf.* Moore, 1988). The low values for *Sphagnum* relative to *Calluna* may indicate drier mire surface conditions (*cf*, Ratcliffe, 1964). The significance of the huge increase in *Sphagnum*, for a single spectrum at 358.0 cm, and in the interpretation of *Sphagnum* curbs in general, is uncertain because of the random variability in *Sphagnum* sporulation and

productivity, which are both species and environmentally dependant (*cf.* Chambers *et al.*, 1997). The peat stratigraphic record generally supports the interpretation of drier mire conditions.

Percentage transmission values are variable during LAS 1a (Figure 6.9). The earliest spectra may reflect a return to drier mire surface conditions after an episode of wetter conditions recorded in the part of the profile not analysed Pollen preservation data reflect a high proportion of corroded grains, indicating drier, more aerobic conditions coimciding with lower percentage transmission values (Figure 6.8; Figure 6.9a). Pollen concentrations decline after 370.0 cm (Figure 6.6), which is not expected with slower peat accumulation rates under drier conditions. It is possible that reduced pollen concentrations might be a by-product of reduced pollen influx from the removal of trees on and around the mire (*cf.* Aaby, 1988; Anderson, 1979) rather than changes in peat accumulation rates. This would need to be tested with further radiocarbon dates. Organic content is 99-95% (Figure 6.10) for most of LAS 1a, indicating that there was no significant mineral in-wash occurring, either from water-borne erosion, or mineral matter deposited by aeolian processes. From 358.0 cm, percentage transmission values reflect a rising trend, the age of this shift cannot be estimated with any precision, but it occurs *ca.* 50-100 years prior to the deposition of the Hekla 4 tephra.

Woodland Destruction: *ca.* ?4,450-4,240 to 4,360-4,090 cal BP (368.0-358.0cm)

LAS1a reflects a remarkable period of woodland disturbance, lasting nearly 120 years. From 370.0 to 368.0 cm, percentages of *Pinus* pollen are slightly greater than the 20-25% widely believed to indicate local growth (*cf.* Bennett, 1984). Between 366.0 and 358.0 cm, pollen percentages undergo a gradual and sustained decline to <8% (Figure 6.5). *Betula*, usually an aggressive coloniser after disturbance, appears to have had a limited capacity to succeed *Pinus*. Pollen percentages of *Betula* increase between 370.0 and 364.0 cm, indicating that *Betula* was able to replace *Pinus* to some extent. However, from 364.0 cm, the continuing reductions in *Pinus* pollen are accompanied by substantial reductions in *Betula* pollen. Except for a brief pulse of recovery from 362.0-360.0 cm, percentages of these two taxa reach a nadir at 358.0 cm

The increase in pollen percentages and concentrations (Figures 6.5 & 6.6) of *Corylus/Myrica* may indicate the increased flowering of *Corylus* in the more open, disturbed woodland (*cf.* Rackham, 1980). However, at 362.0 cm, pollen representation of *Corylus* is also reduced. Other tree taxa are affected. *Sorbus* is absent between 364.0cm and 356.0 cm. During the period of lowest tree pollen percentages around 358.0 cm, there is a gap in *Quercus* pollen. *Ulmus* pollen is sporadic through LAS 1a. Only *Alnus* appears relatively untouched by changes affecting other vegetation in the catchment. Pollen concentrations and percentages of *Alnus* increase after 364.0 cm. It may have been able to replace *Betula* on wetter soils in the catchment. However, other taxa which might have been growing with *Alnus*, such as *Salix*, are absent after 364.0 cm, and *Populus* is not recorded between 368.0 cm and 355.0cm.

Grassland became an increasingly important feature of the landscape as forest cover receded. Percentages of Poaceae pollen, rising since 368.0 cm, peak at 30%. The low tree pollen values, 22%, coupled with grass pollen values >35% indicate substantial woodland clearance (*cf.* Tinsley & Smith, 1974; Tipping, 1997). The more open aspect of the remaining woodland is also attested by the increased frequency of spores of ferns. The rise in *Dryoperteris*, *Polypodium vulgaris* and Filicales percentages reflects the better transport of these spores through the more open woodland (*cf.* Moore, 1988). Light sensitive taxa such as *Anemone nemorosa* are not recorded with the reductions in *Betula* pollen. Shade intolerant herbs such as *Silene dioica*-type. *Vicia*-type and Umbellifers, however, are better represented.

Early Bronze Age Human Activity *ca.* 2500-2290 cal BC

Accompanying this loss of woodland and expansion of grassland is the appearance of agricultural 'indicator species' (*cf.* Behre, 1981). *Plantago lanceolata* is recorded from 365.0 cm (*ca.* 2400 cal BC). The appearance of this herb is accompanied by other taxa commonly associated with dry grassland such as *Rumex* and *Astragulus*. Other herb taxa such as *Succisa*, *Trifolium*-type and *Primula vulgaris* may have grown on poorer, damper areas of grassland. These areas may have also hosted some types of Cyperaceae and *Equisetum* as well as bryophytes such as *Lycopodium* and *Sphagnum* (*cf.* Rodwell *et al.*, 1991b). Cereal-type pollen is recorded at 360.0 cm, with pollen of arable herbs such as *Artemesia*, Asteraceae, Caryophyllaceae and

Chenopodicaeae. Small fragments of microscopic charcoal, mostly 20-30 μm are recorded (Figure 6.7). Burning may have been non-local and restricted to domestic fires. Fire does not appear to have played a role in the destruction of woodland around Loch Ascaig.

The introduction of domestic grazing animals into the catchment may have had a significant impact on the structure of the vegetation. Taxa vulnerable to browsing and grazing such as *Salix*, *Sorbus* and *Populus* disappear from the pollen record as evidence for human activity in the catchment becomes more apparent. Cyperaceae is also sensitive to grazing, which may explain its absence at times when grazing is well represented. Grazing animals, particularly sheep (*cf.* Buckland & Edwards, 1984) would have influenced the seeming inability of *Betula* woodland to either succeed *Pinus* or regenerate itself. Grazing may have also prevented *Calluna* from spreading rapidly into areas of former pine growth, while promoting the relative abundance of grasses over heather for most of LAS 1a (*cf.* Gimingham, 1972; Ritchie, 1955)

Woodland Regeneration and possible Settlement Abandonment

Between 356.0 and 353.0 cm, pollen percentages of trees undergo a remarkably rapid recovery, as combined values rise to nearly 80% in under 100 years (Figure 6.5). However, forest cover may not have been as complete as indicated by percentage data. Lower pollen concentrations (Figure 6.6) of trees may indicate a higher proportion of long distance pollen was being deposited on the mire, particularly *Pinus*. Spores of ferns are less frequently recorded. Shade intolerant taxa such as *Vicia*-type and *Silene dioica*-type are absent, but pollen of *Anemone nemorosa* re-appears in the record. Percentages of *Calluna* and Poaceae decline substantially, reflecting the re-establishment of forest cover. Gaps in the records in grassland/grazing indicators such as *Plantago lanceolata, Pimula vulgaris, Rumex* and *Urtica*, as well as arable herbs *Artemesia*, Asteraceae, Caryophyllaceae and Chenopodiaceae, coincides with the maximum in tree pollen percentages at 356.0 cm (Figure 6.5).

The recovery of *Pinus* lasts just a single spectrum, and from 356.0 cm, pollen percentages are again in decline. Lower percentages, *ca.* 20% at 354.0 cm, coincide with the Hekla 4 tephra horizon. Pollen of herb taxa associate with grazing and

grassland reappears, as do arable herbs, joined by Cruciferae and *Cryptogramma crispa*, a fern commonly found on broken or bare ground (*cf.* Tipping & McCulloch, *unpub.*). Evidence for local burning occurs at 355.0 cm with the first substantial peak in microscopic charcoal, comprised mainly of fragments >70 μm (Figure 6.7). The *Betula-Corylus* woodland does not appear to have been an obstacle to renewed agricultural activities. Despite the declining abundance of *Pinus* pollen and evidence of human activity, there is very little change in proportions of *Betula* and *Corylus/Myrica* pollen.

Lpaz LAS-1b
353.0-338.0cm
Betula-Poaceae-*Calluna*
***ca.* 4,360-4,090 to 4,010-3,820 cal BP**
***ca.* 2410-2140 to–2060-1870 cal BC**

The Post-Pine Decline Environment of Loch Ascaig and Early Bronze Age Human Impacts Continued

At 353.0 cm *Pinus* pollen drops abruptly from 20% to zero. The complete absence of *Pinus* pollen from the record is only temporary, but between 352.0 and 338.0 cm values never exceed 10%. *Pinus*may not have been entirely absent from the catchment, however, as pollen values of 5-10% have been recorded where *Pinus* grows in stressed situations (*cf.* Fossitt, 1984b). The areas of former pinewood appear to have been replaced by a mixture of heath, grassland and probably cultivated areas. The profound reductions of *Pinus* pollen probably allowed for the better representation of *Quercus* pollen which occurs more frequently from 353.0 cm. Increasing pollen percentages and concentrations of *Alnus* after 346.0 cm indicate that it competed successfully with *Betula*, probably replacing *Pinus* where it had grown in wetter areas (*cf.* Bennett, 1984, 1986). The expansion of *Alnus* woodland is accompanied by better representation of other wet woodland vegetation such as *Salix,* Cyperaceae, *Hypericum*, *Filipedula*, *Viola palustris* and the fern *Athyrium felix-femina.*

Percentage and concentration data indicate that *Betula-Corylus* dominated the woodland around Loch Ascaig after the demise of *Pinus*. *Betula* pollen percentages fluctuate gently between 30-40%. *Corylus/Myrica* pollen values are stable at around 10% for most of LAS 1b. Wood macrofossils are recorded frequently after 340.0 cm,

indicating that trees, probably *Betula*, colonised the mire. Human activity in the catchment does not appear to have exerted a great deal of pressure on the post-pine decline deciduous woodland. It does seem, however, that grazing did prevent *Betula-Corylus* woodland or scrub from regenerating in areas of former pinewood. The margins of the *Betula-Corylus* woodland, the most vulnerable to disturbance (*cf.* Edwards, 1981), may have been penetrated on a small scale from time to time. For example, between 352.0-348.0 cm, an area of the *Betula* woodland close to the mire may have been removed. *Sorbus* pollen is absent from these depths, and it, too, may have been affected. Cereal-type pollen is recorded in 3 of the 4 spectra. The removal of *Betula* trees at the mire edge may have facilitated the movement and deposition of these large diameter, poorly dispersed grains (*cf.* Caseldine, 1981). The single brief peak in *Corylus/Myrica* percentages may represent increased flowering of this taxon as a field edge shrub (*cf.* Whittington & Edwards, 1994). Cyperaceae is rare after 348.0 cm, perhaps temporarily diminished by grazing and or burning. The woodland recovers, but evidence for arable activity continues. Cereal type pollen is briefly absent, until 344.0 cm, associated again with modest reductions in *Betula* pollen percentages

The period between *ca.* 2410-2140 cal BC and *ca.* 2060-1870 cal BC is one of pronounced human activity. Herb taxa associated with arable activity are frequently recorded between 353.0 and 338.0 cm and include Caryophyllaceae, Chenopodiaceae, Cruciferae, *Artemesia*, *Plantago media/major*, Lactuceae, and the fern *Cryptogramma crispa*. Poaceae pollen percentages rise gradually until 346.0 cm, peaking at >30% tlp. Dry grassland taxa *Plantago lanceolata* and *Rumex* continue to be recorded, joined by grassland mosses *Disphasiastrum* and *Botrychium lunaria*. *Trifolium*-type, *Urtica*, *Primula vulgaris* and *Succisa pratense* may have grown on damper areas of grassland. After 353.0 cm, proportions of microscopic charcoal rise substantially, with most of the fragments belonging to large size classes. Individual measurement of fragments >70 μm recorded a significant amount *ca.* 500 μm indicating a local source of burning between 353.0 cm and 346.0 cm. After 346.0 cm, fragments are slightly smaller, but the majority are 50 μm or larger, indicating that burning continued nearby. *Pteridium*, growing on acidic, but well drained soils, probably with *Calluna*, is pyrophitic and is better represented with the increased microscopic charcoal fragments.

Calluna percentages recover across the subzone boundary at 353.0 cm. Moderate to light grazing in some areas may have allowed the expansion of *Calluna*, particularly in areas formerly occupied by *Pinus* (McVean & Ratcliffe, 1962). The evidence for local burning coupled with erratic *Calluna* percentages could indicate the use of fire to manage heather. Grazing and burning together may have prevented *Betula* from expanding significantly after the demise of *Pinus*. Burning would have maintained to competitive vigour of heather plants, preventing invasion by *Betula* (Gimingham, 1972), as well as destroying seedlings (Hester & Miller, 1995). Heavy grazing and burning could have led to the dominance of grasses over heather seen between 353.0 and 346.0 cm (*cf.* Legg, 1995). After 346.0 cm, local burning becomes a less prominent feature. A change in regime to lighter grazing and more favourable burning may have been responsible for the gradual replacement of grassland by heather after 346.0 cm.

Mire Communities and Palaeohydrology

Percentages transmission values continue their increasing trend peaking at 350.0 cm before declining. The lower percentage transmission values between 348.0 cm and 340.0 cm are accompanied by an increase in corroded and crumpled grains. From 340.0cm there is a more sustained, but less pronounced, increase in percentage transmission values. The interpolated date of this shift is *ca.* 3,940-3,700 cal BP/1990-1750 cal BC. Taxa characteristic of bogs and wet, marshy situations are more frequent and diverse in the pollen record. These include Ranunculaceae, *Potentilla*-type, *Narthecium ossifragium*, *Lycopodium* and other ericoids. Spores of a fungal parasite of *Sphagnum, Tilletia sphagni* (*cf* Birks, 1975) mirror a rise in *Sphagnum*. The apparent increase in *Potamogeton* and records of *Menyanthes* may indicate the expansion of fen communities, but, again may only represent long distance transport from nearby Loch Ascaig due to the reduction in woodland. With the rise in percentage transmission values, pollen concentrations are reduced from 344.0cm, indicating a faster accumulation rate as a result of wetter conditions. Pollen preservation has improved from LAS 1a. Loss-on-ignition data indicate that organic content fluctuated between 95-98%; mineral in-washing as a result of woodland removal does not seem to have affected the site.

Lpaz LAS 1c
Salix-Betula-Calluna
338.0-224.0cm
4,010-3,820 to 3,480-3,330 cal BP
2060-1870 to 1530-1370 cal BC

Rise of *Salix* woodland

The main feature of LAS 1c is the dramatic rise of *Salix* pollen from 338.0 cm (*ca.* 2060-1870 cal BC), reaching values of 25%, and its abrupt fall at 328.0cm (*ca.* 1730-1570 cal BC). Typically, *Salix* pollen values of 2-3% are considered representative of local growth (Tauber, 1965), because although *Salix* is a prolific pollen producer, its pollen is poorly dispersed (Rempe, 1937). The extraordinary rise in *Salix* pollen percentages and concentrations reflects its dominance of the local vegetation. Pollen percentages and concentration data show that the species rich *Alnus* woodland was sustained. *Populus* is again recorded between 336.0 and 330.0 cm. *Betula* appears to have lost its former importance on the mire, as *Betula* pollen is reduced in both relative and absolute frequencies. However, percentages of *Betula* and *Corylus* indicate that they continued to be important in the woodland surrounding the mire, accompanied by *Sorbus*. Increased pollen frequencies of *Fraxinus, Juniperus communis* and *Pinus* reflect the increasing openness of the woodland, representing both light loving taxa such as *Fraxinus* and increased long distance transport of *Pinus*.

Human Impacts

Significant changes appear to have taken place on the agricultural land surrounding the mire as well. The rise of *Salix* woodland coincides with a reduction in grazing activity. Grassland continued to be replaced by heath in some areas, as Poaceae pollen percentages and concentrations undergo sustained decline, mirrored by steadily rising *Calluna* pollen percentages and concentrations. Dry grassland indicators — for example, *Plantago lanceolata, Rumex, Botrychium lunaria* — are reduced in frequency and variety between 336.0 and 328.0 cm. Pollen percentages of *Urtica*, one of the most nutrient demanding and basophilous herb taxa recorded, rise to 2% at 336.0 cm, also promoted by the inferred eutrophication. During the period of peak *Salix* pollen values, arable activity is better represented by the pollen data. Cereal-type pollen is recorded in contiguous spectra from 338.0 to 328.0 cm. It is accompanied by less consistent records of herbaceous taxa associated with arable activity which include *Artemesia,* Asteraceae, Cruciferae, *Plantago media/major* and

Chenopodiaceae. The bare ground indicator, *Cryptogramma crispa* (*cf.* Tipping & McCulloch, *unpub*), is joined by *Radiola limnoides*, an herb characteristic of open, damp, sandy places (Stace, 1991). Proportions of microscopic charcoal are reduced across the subzone boundary at 338.0 cm. The predominance of fragments measuring 20-30 μm from 338.0-330.0 cm indicates burning was not taking place locally.

Mire Communities and Palaeohydrology

Salix appears to have also replaced *Calluna*, as well as *Betula*, on parts of the mire. Although over all pollen values for *Calluna* are increasing, depressions in pollen percentages and concentrations of this taxon coincide with peak values of *Salix* between 334.0 and 330.0 cm. The increased representation of vegetation types characteristic of wet, boggy and acidic environments in LAS 1c, is interrupted by the establishment of *Salix*, but continues after its decline at 326.0 cm and include taxa characteristic of fen communities such as *Menyanthes trifoliata* and *Lobelia dortmanna*. *Potamogeton* is absent, but since it is wind-pollinated and was probably growing nearer to the loch, the predominance of *Salix* may have adversely affected its representation. Cyperaceae and *Sphagnum* also appear to have been temporarily displaced from the mire, only recovering with the demise of *Salix* after 328.0 cm. Percentage transmission data continue the generally increasing trend, with minor fluctuations, which was established in LAS 1b and is maintained throughout most of LAS 1c. Total pollen concentrations remain largely unchanged.

The Decline of *Salix*

The abrupt decline of *Salix* is reflected by both percentage and concentration data of this taxon. *Salix* is reduced from peak values of 25% at 330.0 cm, to around 3% at 328.0 cm. At 328.0 cm, there is considerable peak in microscopic charcoal, mostly comprised of fragments >70 μm, implying that burning was used to clear *Salix* woodland from the mire surface. After 328.0 cm, proportions of microscopic charcoal are reduced, but larger fragments, especially >70 μm continue to be well represented. The destruction of *Salix* appears to be associated with a change an emphasis on agricultural activities from arable to pastoral. Cereal-type pollen is absent after 328.0 cm and there are gaps in arable indicators Chenopodicaeae and Caryophyllaceae. After the decline of *Salix*, rises in Cyperaceae are mirrored by *Sphagnum*, indicating a return to more acid — and more open (*cf.* Huntley & Birks, 1983) — conditions.

Salix appears to have briefly maintained a local presence, but after 326.0 cm, its pollen is reduced to rare occurrences, indicating it was probably once again restricted as a shrub in the wet *Alnus* woodland. On the mire surface, *Salix* appears to have been replaced predominately by *Calluna*. Pollen percentages and concentrations of this taxon rise substantially after 328.0 cm. *Betula* pollen percentages do not immediately respond to the absence of *Salix*, but by the end of the subzone at 324.0 cm, pollen percentages reflect the recovery of the *Betula* woodland. Grassland as an important component of the landscape had been in decline since 345.0 cm, gradually giving way to heath. After the destruction of the *Salix* woodland, percentages of Poaceae pollen are reduced to *ca.* 10% tlp. The reduction in grasses and expansion of *Calluna* percentages indicate that *Calluna* was increasingly becoming a major feature of the landscape away from the mire. Some restricted areas of grassland may have persisted, however, because with the re-establishment of grazing after 328.0 cm, *Plantago lanceolata, Rumex, Trifolium*-type and other pastoral type herbs are better represented.

Potential Mechanisms for the Establishment of Salix Woodland

The concomitant expansion of *Salix* and *Urtica* may not be coincidental. Compared to many of the other taxa represented in the pollen assemblage, *Salix* and *Urtica* are more nutrient demanding and basophilous than most of the other taxa represented in the pollen assemblage. In fact, the development of these vegetation types in upland situations similar to the Strath of Kildonan is considered unusual because of the lack of suitable base-rich or calcareous situations (Rodwell *et al.*, 1991a). In northeast Scotland it has been suggested that such vegetation types can develop when situated in calcareous bedrock or drifts (Birse, 1980, 1984). The bedrock around Loch Ascaig is primarily acidic, comprised mainly of mica-schists and siliceous or semi-pelitic granulites. The slopes of Ceannbhaid andMid Hill host drift deposits, and the NW shores of Loch Ascaig and the banks of the Allt Ceann a'Bheithe may have provided nutrient rich substrates, although they are some distance from the sampling sites. However, a second smaller drift deposit it located within the basin *ca.* NC 8350 2550, and may have provided a suitable substrate.

The sudden expansion of these two taxa, *Salix* and *Urtica*, especially considering the steadily increasing prominence of acidophilous bog vegetation since before the pine decline, strongly hints at the onset of an allogenic eutrophication process. A similar reversal in acidification resulting in the establishment of *Salix* woodland was recorded between 4,435 and 2,745 cal BP in a raised mire in Wales (Hughes & DuMayne-Peaty, 2002). There, it was suggested that anthropogenic woodland clearance may have triggered increased surface runoff and erosion of mineral nutrients into the catchment, allowing *Salix* to flourish.

By decreasing demand, forest disturbance can enhance the nutrient status of soils, an effect which can least for several decades (Matson & Boon, 1984). The increased soil surface runoff also results in a drier soils surface after clearance (Swank & Douglas, 1974), a process which could also have allowed the additional release of nutrients through the oxidation of organic matter (Rodwell, *et al.*, 1991a). Unlike Waun-Figlen Fen, loss-on-ignition data from LAS do not indicate any significant changes in the organic content of the sediment. If nutrients were being washed into the catchment through the erosion of minerogenic sediments, they were not reaching the sampling site.

At Loch Ascaig it is not immediately apparent what could have triggered the profound change in vegetation. Since at least *ca.* 4,450 cal BP, *Salix* had probably been present in the catchment, growing as a shrub in the wet *Alnus* woodland, but there are no indications it was ever locally present. Unlike the situation in Wales (*cf.* Hughes & DuMayne-Peaty, 2002), the *Salix* rise does not appear to follow a period of substantial deforestation, at least on the scale of the pine decline, several hundred years earlier. Rather, it appears that since *ca.* 2100 cal BC, woodland cover around Loch Ascaig had been steadily eroding.

Another potential avenue for the development of *Salix* woodland is the physical disturbance of the mire surface. *Salix* has been observed as a coloniser of abandoned peat cuttings or after other disturbances on mires such as mowing (Giller & Wheeler, 1986;Rodwell, *et al.*, 1991a). Peat extraction has been practiced in Scotland since prehistoric times, for use as fuel, building material and manure (Carter, 1998a & b; Dickson, 1998). Although not immediately testable from the present set of

archaeological and palaeoenvironmental data, peat cutting as a stimulus for the development of *Salix* woodland should be considered as a probable cause.

The establishment and continuation of *Salix* woodland for several hundred years is remarkable because of the evidence for the maintenance of agricultural activity nearby. Salices in general are highly sensitive to burning and grazing. During peak *Salix* values between 334.0 and 330.0 cm, evidence for arable activity is much more prominent. Palynological indicators of grazing and burning continue to be recorded between 334.0 and 328.0 cm, but their representation is comparatively low. The persistence of *Salix* might be a result of management; it coppices well, unlike many of the other tree and shrub taxa in the catchment, with the exception of *Corylus avellana* (*cf.* Evans, 1992).

Salix may have been somehow protected from grazing animals, either intentionally or as a by product of the extant system of managing livestock, which restricted animals to other areas of the catchment. The existing fragments of walls and banks associated with the Loch Ascaig settlements, and the absence of a reliable chronology, provide little or no means of reconstructing the agricultural landscape associated with these vegetation changes. In any case, fencing and stock pens may have been constructed out of hurdling — perhaps willow? — leaving no trace of their former existence.

Lpaz LAS 1d
324.0-314.0cm
Betula-Corylus/Myrica-Calluna-Poaceae
***ca.* 3,480-3,330 to 3,080-2,870 cal BP**
***ca.* 1530-1370 to 1130-920 cal BC**

Later Bronze Age Human Activity and Impacts on Vegetation

The relationship between heathland and woodland appears to have become increasingly unstable from *ca.* 1520 BC. An initial phase of woodland recovery between 324.0cm and 320.0cm may be related to a short term abandonment of the catchment. Percentages of *Betula* continue the rising trend initiated at the close of LAS 1c. *Corylus/Myrica* achieves 10-15%tlp for much of LAS 1d, indicating it was probably forming a more significant part of the canopy in a more open *Betula* woodland. Between 324.0 and 319.0cm, pollen concentrations of this taxon are also substantially higher than any previously recorded. Shade intolerant herbs such as

Silene dioica-type, *Heracleum sphondylium* and *Vicia*-type are frequently recorded. *Allium*-type is recorded, but may not represent cultivated types, several of which are later introductions to Britain (*cf.* Stace, 1991). *Allium ursinum* has been observed as a frequent component in the field layer of modern open birchwoods in Sutherland (McVean & Ratcliffe, 1962). Substantial reductions in pollen percentages and concentrations of *Alnus* between 324.0 and 322.0 cm indicates it may have been temporarily replaced in wetter areas by *Betula.*

Increased values for *Betula* and *Corylus* coincide with substantially reduced proportions of microscopic charcoal, *ca* 60% measure 20-30 μm, indicating a non-local source. Grazing indicators such as *Plantago lanceolata*, *Rumex* and *Trifolium*-type are absent between 324.0 and 322.0 cm. Reduced grazing pressure and burning would have allowed *Betula* to establish itself in the Callunetum. In addition to evidence suggesting reduced pastoral activity, arable activity also appears to have been briefly interrupted. Arable indicator species such as *Artemesia*, Caryophyllaceae, Cruciferae, *Plantago media/major* and Chenopodiaceae are absent between 324.0 and 322.0 cm. Cereal-type pollen is also absent.

From 322.0 cm, both grazing and arable activity are apparent in the pollen record. Palynological evidence for renewed human activity is not associated with the immediate clearance of the re-established woodland, which persists until 320.0 cm. After this depth, human activities appear to have seriously impacted the *Betula* component of the woodland, because pollen percentages of this taxon are significantly reduced between 320.0 and 317.0 cm. Large wood fragments are recorded between 320.0 and 314.0 cm, indicating that some trees were, however, still present on the mire. *Corylus* does not appear to have been similarly affected, as pollen percentages remain above 15%. Disturbances affecting parts of the *Betula* woodland may have allowed *Alnus* to re-establish itself in wetter areas. Although some instability is also reflected in the wet *Alnus* woodland, as pollen percentages and concentrations of this taxon are erratic after 320.0 cm.

From 321.0 cm, proportions of microscopic charcoal increase substantially, with 30% of fragments >50 μm, and 35-40% >70 μm indicating burning was renewed nearby. The increase in microscopic charcoal is accompanied by gradual increases in the

abundance of *Calluna* pollen. Herb and moss taxa associated with grazing and/or grassland such as *Plantago lanceolata*, *Trifolium*-type, *Huperzia selago*, *Botrychium lunaria* and *Urtica* also continue to be strongly represented. Cereal-type pollen continues to be absent, but pollen of arable-type herbs is diverse and frequently recorded. *Papver* is recorded for the first time from 322.0 cm. *Linum ussitassimum*, recorded at 316.0 cm, may have been grown as a cultivated crop (*cf.* Behre, 1981). *Linum* is a poor pollen producer and its pollen is likely to indicate local growth of the plant (*cf.* Hall, 1990).

Rumex is well represented and attains values of 10% at 322.0 cm and again 316.0 cm. Interpretation of composite *Rumex* curves can be problematical; for the most part, the high percentages recorded here exclude the possibility that *Rumex* was growing as part of the local wetland vegetation (*cf.* Behre, 1981). High percentages of *Rumex* pollen, like those recorded in LAS 1d are more often associated with ecosystem disturbance (*cf*, Huntley & Birks, 1983). Abundant *Rumex* pollen has been associated with high minerogenic input. The increase in *Rumex* also coincides with a substantial increase in pollen frequencies of the bare ground taxa *Cryptogramma crispa*. The rise in *Rumex* is post-dated by a decline in organic content at 318.0 cm to 84%, the first such change recorded in the sediment. It is not a substantial change, but considering that loss-on-ignition values have remained between 95% and 99% for most of the profile, despite evidence for frequent disturbance of the vegetation cover, it may indicate that Loch Ascaig is not a sensitive record of erosion in the catchment.

The replacement of *Betula* woodland by heath was relatively short-lived. After 319.0 cm, *Calluna* percentages and concentrations are sharply reduced, with *Calluna* pollen actually becoming rare in the record by 314.0 cm. *Betula* percentages recover previous values of 40%, although pollen concentrations are substantially reduced. *Corylus* pollen percentages and concentrations, however, do not show signs of recovery until 314.0 cm. It is unclear why *Corylus* failed to retain its former place in the open *Betula* woodland after 318.0 cm, although grazing and clearing of woodland may have placed some pressure on *Corylus/Myrica*. *Pinus* values rise to >10%. This may represent local growth of *Pinus* in stressed situations (*cf.* Fossitt, 1994). The declining forest canopy also would have meant that long distance pollen, particularly wind-pollinated taxa like pine and *Fraxinus*, would have been better represented.

Substantial rises in Poaceae pollen concentrations and percentages indicate the expansion of grassland. Despite the re-establishment of *Betula* woodland, evidence for local burning continues to be strong. Intense grazing and burning may have caused some areas of *Calluna* heath to be converted to grassland (*cf.* Legg, 1995). Percentages of grass pollen, 30-40% tlp, may have also originated in the field layer of the open *Betula* woodland (*cf.* Birks, 1972). Cereal-type pollen is still absent from the record, but arable herbs continue to be recorded. After 316.0 cm, woodland is again in decline, except for *Corylus/Myrica* which shows signs of recovery from 314.0 cm.

Mire Communities and Palaeohydrology

Percentage transmission values reflect an elevation in values after 316.0 cm. The relationship of this change to climate is less certain than previously because of the high degree of human activity apparent in the pollen record. The shift may reflect vegetation dependent changes in catchment hydrology related to the disappearing woodland cover. The evidence for increased burning may also have affected hydrology, as charcoal has been demonstrated to reduce the porosity of soils (*cf.* Mallik *et al.*, 1984). The timing of the shift, *ca* 3,080-2,870 cal BP (1130-920 cal BC), does, however, broadly agree with evidence from peat bog stratigraphy indicating wetter climate conditions: in Wester Ross *ca.* 3,000 cal BP (Anderson, 1998), and at Cross Lochs Caithness *ca.* 2,890-27,50 cal BP (Charman, 1990), as well as other humification records in the British Isles between 3,300-3,000 cal BP (Blackford, 1990; Barber, *et al.*, 1994).

The persistent percentage transmission values are generally associated with better representation of mire taxa which include Cyperaceae, *Sphagnum, Potentilla*-type, *Narthecium ossifragium*. *Lycopodium* is better represented with increase in *Calluna* and may have been growing on wetter areas of heath. *Disphasiastrum* may have been growing along the woodland/mire margin. Increases in percentages of *Sphagnum* are associated with more consistent records of *Tilletia sphagni*. The better representation of *Potamogeton*, a wind-pollinated aquatic taxon, is probably related to the reduction in density of tree pollen after 318.0 cm, allowing better representation of more distant vegetation. The trend towards wetter mire surface conditions appears to be supported by increased representation of taxa characteristic of wet, acidic mire conditions.

The relationship between persistent wetter mire surface conditions and higher Cyperaceae percentages is not straightforward, however. Changing proportions of Cyperaceae pollen appear to be more closely related to evidence for burning on the mire surface. In particular, the large peak in charcoal fragments >70 μm at 320.0 cm is associated with an abrupt reduction in Cyperaceae. Similarly, proportions of *Calluna* appear to be closely linked with evidence for grazing and burning regimes than mire hydrology. The trend towards wetter mire conditions also appears to be at odds with the pollen preservation data, which indicate a marked increase in corroded and degraded grains from 320.0cm. This coincides with the evidence for renewed burning on the mire surface, which may have damage pollen grains on the surface of the mire (*cf.* Andersen, 1979).

Lpaz LAS 2a
314.0-293.0cm
Corylus/Myrica-Calluna-Poaceae
***ca*.3,080-2,870 to 2,160-1,940 cal BP**
***ca*. 1130-920 cal BC to 230 cal BC-cal AD 10**

Woodland decline

Relative and absolute pollen frequencies of *Betula* continue to decline throughout LAS 2a. The reduction in *Betula* percentages is symptomatic of what appears to be the general erosion of woodland after *ca.* 1130-920 cal BC. *Sorbus* pollen is infrequently recorded, restricted largely to a phase of *Betula* recovery between 306.0 and 300.0 cm. As *Betula* pollen values continue to decline, herbs associated with the woodland become less frequent and diverse, reduced to an occasional *Vicia*-type or *Silene dioica*-type. No wood macrofossils are recorded between 314.0 and 293.0 cm.

The presence of *Quercus* pollen may reflect primarily long distance transport because it is only recorded during periods of reduced *Betula* pollen frequencies, as are *Fraxiuns* and *Ulmus*. Percentage and concentration data indicate reductions in *Alnus* between 314.0 and 308.0 cm. Pollen of both *Salix* and *Populus* are absent after 308.0 cm, indicating a real reduction in the extent of wet *Alnus* woodland. The only exception to the general rule of declining woodland in the catchment appears to be *Corylus/Myrica*. From the beginning of LAS 1d, this pollen type began contributing significantly more to the pollen rain than at anytime previously. In LAS 2a, absolute

and relative pollen frequencies of *Corylus/Myrica* are erratic, but indicate that it may have successfully replaced *Betula* as the dominant vegetation type in some areas of the catchment.

Later Bronze Age Human Activity

Arable activity continues to be well represented in LAS 2a. Cereal-type pollen is once again recorded. Its presence could be related to the inferred absence, or at least substantial reduction, of woodland on or fringing the mire (*cf.* Caseldine, 1981; Edwards, 1981). However, the pollen evidence also indicates an increasing emphasis towards pastoral activity. In particular, the close relationship between the microscopic charcoal curve and the abundance of *Calluna* pollen first noted in LAS 1d, appears to continue into LAS 2a. *Calluna* percentages recover rapidly from the low values recorded at 314.0 cm. Percentages of this taxon are highly variable, but reach 50% by 296.0 cm.

Some areas of grassland may have been invaded by heath, as percentages and concentrations of Poaceae are reduced across the subzone boundary. However, in other areas grassland was able to persist between *ca.* 1130-cal AD 10. *Polygala vulgaris*, an indicator of ancient grassland is recorded (*cf.* Grime *et al.*, 1990). Other herbaceous taxa associated with dry grassland such as *Plantago lanceolata* and *Rumex*, as well as *Botrychium lunaria* continue to be recorded, but herbs characteristic of damper, poorer grassland are comparatively more abundant. These taxa include: *Succisa pratense, Thalictrum*, *Trifolium*-type, *Primula vulgaris* and the moss *Selaginella selaginoides*. *Huperzia selago* would have been growing on areas of grassy heath. However, after 308.0 cm the frequency and diversity of herb taxa is markedly reduced.

A more favourable management regime, or somewhat reduced grazing pressures may have existed after *ca.* 1130-920 cal BC. There are no indications that intense grazing posed a significant threat to the expansion of heathland, although grasses are somewhat better represented between 311.0 and 309.0 cm, coincident with a rise in proportions of microscopic charcoal fragments. Instead, reductions in the abundance of *Calluna* pollen at 306.0 cm and again at 300.0 cm are associated with reductions in proportions of microscopic charcoal fragments and increased abundance of pollen of

tree type, particularly *Betula*, but pollen data indicate that the wet *Alnus* woodland also recovered as well. After 308.0 cm, there is a general reduction in the frequency of microscopic charcoal fragments, although fragments >50 μm continue to make up more than 60% of the total recorded. Agricultural activity continues to be recorded, but it seems that the focus of activity may have moved elsewhere in the catchment, permitting woodland to regenerate around the mire. The apparent dereliction of areas of *Calluna* heath during brief episodes of woodland recovery and low microscopic charcoal evidence presents a strong case for its inferred management.

Mire Communities and Palaeohydrology

Percentage transmission values remain relatively stable until 296.0cm. Pollen concentrations are reduced and pollen preservation is generally good, supporting the inference of generally wet mire surface conditions, Percentage transmission values are reduced temporarily between 292.0 and 294.0 cm. Although accompanied by brief increases in corroded grains and pollen concentrations, this change does not appear to be directly related to any vegetation changes, or other stratigraphic changes which might indicate a significant shift in mire hydrology.

Cyperaceae pollen percentages are reduced across the zone boundary at 314.0 cm. The abundance of sedges was probably adversely affected by burning and grazing. With inferred reduction of local burning after 308.0 cm, Cyperaceae is somewhat better represented. Taxa characteristic of wet, acidic, 'boggy' situations increase in frequency and variety. *Sphagnum* values increase to 40% by 303.0 cm. Increases in *Sphagnum* are accompanied by substantial increases in the frequency of *Tlletia* spores. Other taxa include the fern *Thelypteris palustris*, which is one of the few ferns which enjoys particularly waterlogged environments (*cf.* Fitter *et al.*, 1984), and acidophilous taxa such as *Drosera* and *Valeriana*. *Potentilla*-type, *Viola*, *Menyathes* and Ranunculaceae continue to contribute to the record. Aquatics such as *Lobelia* and *Potamogeton* are recorded, joined by *Nuphar*. *Potamogeton* reaches 5% tlp at times. The increased representation of aquatics may indicate pooling on the mire surface.

The combined high percentages of *Calluna* and *Sphagnum* may indicate the expansion of blanket mire communities (*cf.* Fossitt, 1994a) away from the mire. Inferring the

expansion of bog vegetation into other areas of the catchment is complicated, however, because these taxa were growing on the mire surface, as well as on dry land. The increased abundance of *Calluna* and *Sphagnum* may simply reflect their increasing importance on the mire surface. The declining contribution of pollen from trees and other 'land' taxa might skew pollen representation towards mire communities.

Possible Woodland Management

Calluna may not have been the only natural resource under management since *ca.* 1530-1370 cal BC. The increased importance of *Corylus/Myrica* over *Betula* in LAS 2a is somewhat unexpected. Both the pollen assemblage and the palaeohydrological record indicate that conditions in the catchment were increasingly wet and acidic from *ca.* 1130-920 cal BC. The persistence of wetter conditions may have led to the leaching and gleying of soils. *Alnus*, as well as *Salix*, will not tolerate extremely acid soils (Savill, 1991). The sustained reduction of *Alnus* pollen throughout LAS 2a may reflect the trend towards increasingly acidic soil conditions in the catchment. In general, pollen of tree taxa characteristic of better drained, less acidic habitats, *eg. Ulmus, Fraxinus, Quercus*, is less frequently recorded after 308.0 cm.

Corylus is generally intolerant of acidic soils, and appears to be dominating the woodland at a time when conditions appear to be increasingly inimical to other taxa with similar preferences. *Betula*, in particular, is tolerant of acid soils but appears to lose out to *Corylus* anyway. The changes at Loch Ascaig may represent a natural pattern of succession (*cf.* Miles, 1988), but this does not explain the ability of *Corylus* to overcome the inferred edaphic limitations that kept it from becoming more prominent prior to *ca.* 1500-1300 cal BC. Nor does it explain the ability of *Corylus/Myrica* to regenerate while woodland in general is declining. The evidence for continued waterlogging and expansion of mire communities indicates the likelihood that *Myrica gale* may be contributing to *Corylus/Myrica* pollen. *Myrica gale* is a poor pollen producer (Birks, 1973), and the high percentages and concentrations reflected in LAS 2a indicate that changes are more closely linked with the abundance of *Corylus avellana* in the catchment, rather than *Myrica gale*.

Coppicing of *Corylus* will increase flowering and pollen productivity, while reducing that of *Betula* (Rackham, 1980, 1988). However, *Betula* does not coppice as readily or as easily as *Corylus* (Evans, 1992). The highly erratic values of *Corylus/Myrica* since 322.0 cm may reflect periods of coppicing followed by harvesting. Peterken (1992) has described coppice woodlands as dynamic systems at very small scales. As patches are cut down, younger growth reaches the canopy, woodland margins expand when grazing pressure is relaxed, while the edges are pushed back when pressure is restored, pastures can be converted to scrubland, and then cleared again as needed.

Coppicing is defined as a forest crop raised from the cut stumps, or stools, of previous crops and is practical way of regenerating tree crops in a short period of time, usually less than 30 years (Evans, 1992). If such a system was in place it might explain the dynamic and rapid changes in woodland composition from *ca.* 1500-1300 to 420-320 cal BC. The existence of such a system can only be speculated however. The chronological and spatial resolution of the pollen record, as well as the archaeological record is to low to infer with much certainty the precise human influences on woodland dynamics.

Lpaz Las 2b
293.0-276.0cm
Calluna-Betula-Corylus
2,160-1,940 to 2,066-1,870 cal BP
230 cal BC-cal AD 10 to 120 cal BC-AD 80

Iron Age Human Activity

From *ca.* 230 cal BC-cal AD 10, human activity, with occasional exceptions, does not appear to have been local. Arable activities appear to have been maintained, represented by records of cereal-type pollen, *Artemesia*, Caryophyllaceae, Chenopdicaceae, perhaps *Rumex*, which reflects peak values of 2% at 292.0 cm, *Fumaria, Radiola linoides, Papaver, Plantago media/major* and *Cryptogramma crispa*. *Malva sylvestris*, which is usually associated with broken ground or arable activity (Stace, 1991), is recorded for the first time*. However, after 284.0cm,

* Andrews *et al.* (1985) recorded *Malva sylvestris* at Upper Suisgill, but were cautious of the identification, as pre-Roman records of this taxon were previously unknown (Godwin, 1975). Stace (1991) classifies *Malva sylvestris* as a native plant. John Anthony indicates that *Malva sylvestris* occurred frequently in the Strath of Kildonan during mid-20th century vegetation surveys of Sutherland (Kenworthy, 1972). The first occurrence of *Malva sylvestris* at Loch Ascaig is 1cm above the Glen

evidence for arable activity is greatly diminished, limited to a few infrequent occurrences of arable-type herbs. Herbaceous taxa associated with grazing are also declining in frequency. Occurrences of *Plantago lanceolata Trifolium*-type and *Urtica* are somewhat reduced, but are found consistently between 292.0 and 278.0 cm. *Pteridium* is also recorded less frequently, although is better represented during periods of enhanced *Calluna* representation. .

The ongoing reductions of tree pollen in absolute and relative terms also indicates that trees were either not growing nearby, or were reduced to a few fragments of woodland or widely scattered individuals (*cf.* Bunting, 2002). No wood macrofossils are recorded between 292.0 and 276.0 cm. *Alnus* pollen all but disappears from the record in this subzone. Percentages of 2% or less during periodic episodes of general woodland recovery indicate a sparse presence (*cf*, Huntley & Birks, 1983). *Pinus* pollen, mostly rare, achieves better representation along with other tree taxa during episodes of woodland recovery. The decline in absolute and relative frequencies of *Corylus/Myrica* may reflect increasing acidification and waterlogging of soils in the catchment.

The primary feature of LAS 2b is the dynamic relationship between woodland and heathland. A dynamic relationship between these two features of the landscape had been in place since at least *ca.* 1530-1370 cal BC, and was strongly linked to burning and other agricultural activities. From *ca.* 230 cal BC-cal AD 10, evidence for the management of heathland is greatly reduced, but continued activity elsewhere in the catchment may have continued to influence the structure of the vegetation. *Calluna* is reduced across the subzone boundary as *Betula* recovers at 292.0 cm. This change in vegetation is associated with substantially reduced proportions of microscopic charcoal, with fragments predominately measuring 20-30 μm. The re-establishment of *Calluna* at 288.0 cm is not accompanied by evidence for local fire activity. Microscopic charcoal is infrequently recorded throughout LAS 2b, except for a peak

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Garry tephra, conventionally dated to 2100 ^{14}C years BP, or 210 BC-AD 10 in calibrated calendar years. Glen Garry is still relatively imprecisely dated and it is possible that it falls in the older age range (see text for a more detailed discussion), indicating a pre-Roman age for the *Malva sylvestris* horizon. On the other hand, if there is also a strong possibility that this represents a younger horizon, more closely related to the Roman occupation of Scotland. This particular issue of a potential human influenced plant migration/invasion needs to be resolved with better dating and future palaeoecological investigations.

in fragments >70 μm at 282.0 cm.This peak marks a short-lived episode of burning and high grazing pressure, which resulted in the conversion of some areas of heathland to grassland. It may have been restricted to area close to the mire, allowing the regeneration of *Betula* woodland elsewhere in the catchment.

Natural Woodland Succession in Upland Environments

The periodic ebb and flow between *Betula* woodland and *Calluna* heath may reflect natural patterns of upland forest succession. Although several thousand years of human activity may have left an indelible stamp on the structure of the upland vegetation around Loch Ascaig, palynological evidence for human activity is very low for most of the subzone. The relocation of activities away from Loch Ascaig, first apparent in LAS 2a, may overlap with the construction of the brochs at Feranach and Altanduin. The increasing openness of the landscape, and therefore, the ever increasing pollen source area (*cf.* Prentice, 1985) means that processes and activities taking place in different areas of the landscape increasingly form more and more a composite impression. This not only true of 'natural' and 'cultural' processes, but as the landscape becomes more open spatially discrete processes, perhaps separated by large distances, become increasingly homogenised.

Miles (1988) has argued that vegetation communities in the Scottish uplands are 'dynamic', that they move through the landscape over time through natural regeneration cycles and succession. In the absence of strong evidence of burning since *ca.* 420-350 cal BC, the patterns seen in LAS 2b may reflect natural dynamics between woodland and heath. When heathland is managed by fire, the heather plants are kept in the 'pioneering' and 'building' phase and are never allowed to 'mature' or 'degenerate' and are able to exclude *Betula* (Legg, 1995). In the absence of burning, areas of heathland may have been allowed to reach the degenerate phase, facilitating the invasion of *Betula* (Gimingham, 1972,1984; Legg, 1985).

Conversely, as stands of *Betula* reached maturity and died off, *Calluna* would have filled the gap. *Betula* does not form a persistent seed bank, just 2-3 years (Miles, 1988) compared with *Calluna* whose seeds may remain viable for 150 years (Legg, 1985). According to Miles (1988) *Betula* establishment is dense *ca.* 50m from the parent trees, becoming increasing thin up to *ca.* 500m. *Betula* saplings are also shade

intolerant (Gimingham, 1985), so re-establishment would have to take place outwith the shade of the parent stand, also isolated from competition with young *Calluna* plants and in the absence of browsing animals, particularly sheep (*cf.* Buckland & Edwards, 1984). 'Natural' grazing by deer is less of an issue, as deer do not tend to graze birch saplings, except during harsh winter conditions (Hester & Miller, 1985). These two communities, heathland and *Betula* woodland, could have 'migrated' around the landscape as one community died off and suitable habitats became available (*cf.* Miles, 1988). The step-wise nature of the recovery and decline of woodland may reflect the spatial patterning in the dynamics between woodland and heath (*cf.* Brown, 1988), as woodland appears to have either regenerated further away from the site, or it may reflect the gradual reduction in the spatial extent of woodland cover.

Mire Communities and Palaeohydrology

Percentage transmission values increase substantially at 292.0 cm. This occurs just above the Glen Garry tephra horizon which provides a *terminus post quem* of *ca.* 2,160-1,940 cal BP (230 cal BC-AD 10) for the shift. However, the higher percentage transmission values are followed by reductions in the abundance of *Sphagum* spores after 284.0 cm, as well as reduced percentages of Cyperaceae. Taxa characteristic of wet, acid situations continue to be recorded, although not as abundant and diverse as previously. Pollen preservation is generally very good, except for a peak in corroded degraded grains which coincides with evidence for burning on the mire surface. Total pollen concentrations are further reduced after 288.0 cm, which would also seem to support a faster accumulation rate associated with wetter conditions, and is discussed in further detail in the following section.

Some Chronological Considerations

Based on the tephrochronology, which shows the Glen Garry tephra at 292.0 cm (*ca.* 2,100 ^{14}C years BP) and radiocarbon date AA-51425 at 276.0cm (*ca.* 2010 ^{14}C years BP), peat accumulation rates appear to have accelerated to *ca.* 1.9mm year $^{-1}$. Accumulation rates in more recent peats have been shown to reach *ca.* 2.0mm year $^{-1}$ (Franzén, 1992), so an accumulation rate of 1.9mm year $^{-1}$ is not improbable. However, the four-fold increase is abrupt and does seem unusual. Changes in sedimentation might broadly agree with changes in mire hydrology inferred from the

humification record. However, radiocarbon assays are too widespread to reliably constrain sediment accumulation rates.

The Glen Garry tephra has not been subject to the rigorous dating applied to the Hekla 4 tephra, either in the number of dates obtained, *eg.*, Dugmore *et al.* (1995) and Larsen & Thorarinsson (1977), or the high precision multiple sample date obtained by Hall *et al.* (1994). Although it has been found at 11 sites in Scotland, excluding the two in this study, only 3 radiocarbon dates are available and provide an age range of 2,350 and 1,827 cal BP. It is possible, therefore, that the age of the Glen Garry tephra could actually be slightly earlier than the estimated calibrated range (based on Dugmore *et al.*'s 1995 estimated age of the tephra as *ca.* 2,100 ^{14}C years BP). Because of the uncertainty implied by the large error margin on the date of the Glen Garry tephra, it is difficult to evaluate how much peat accumulation rates might have been altered. The other possibility is that the radiocarbon date is too old, but without further dating measures, it would be unwise to either reject AA-51415 as anomalous, or place too much emphasis on the precise 'date' of the Glen Garry tephra.

Lpaz LAS 2c
274.0-216.0cm
Calluna-Poaceae
2,066-1,870 to 1,520-1,350 cal BP
120 cal BC-AD 80 to cal AD 430-600

Human Impacts from the End of the Iron Age into the 'Dark Ages'

The period between *ca.* 120 cal BC-cal AD 80 until *ca.* cal AD 430-600 reflects minimal human impacts on the vegetation. Arable activity may have persisted somewhere within the pollen catchment, represented by occasional cereal-type pollen, *Artemesia*, Caryophyllaceae, Chenopodiaceae and Cruciferae. Poaceae percentages rise substantially after 272.0 cm, and fluctuate between 20-25%. However, pollen of herbs typically associated with grassland, *eg*, *Rumex, Plantago lanceolata*, and *Urtica*, is also less frequent in the record. Proportions of microscopic charcoal are further reduced across the subzone boundary, and are mostly comprised of fragments 20-30 μm. The pollen assemblage is dominated by *Calluna*, at 40-70%tlp, but burning does not appear to have favoured the increase of *Calluna* over *Betula* woodland from 274.0 cm. *Betula* percentages fluctuate between 20-30% during LAS 2c, perhaps

reflecting the persistence of small fragments of woodland in a mostly open landscape (*cf.* Bunting, 2002). Relative and absolute frequencies of *Corylus/Myrica* pollen are also reduced. *Myrica gale* may have been increasingly contributing to the pollen of this type.

There is some evidence that human activities impinged locally from time to time, however. At 270.0 cm, there is a brief peak in microscopic charcoal fragments >70μm. Although strangely, this coincides with an increase in woodland and reduction in *Calluna*. The apparent disparity between burning and vegetation changes may reflect the increasingly non-specific pollen source area of the more exposed landscape. *Calluna* percentages recover rapidly and reflects sustained rise in values. Between 240.0 and 230.0 cm, microscopic charcoal fragments >70 μm increase substantially, and may have affected the abundance of *Calluna* locally. There are some indications in the pollen data of the 'pyric succession' described by Gill and Groves (1983), where other ericaceous taxa and grasses becoming increasingly prominent after burning of *Calluna*. 'Pyric successions' may be reflected in the pollen record earlier, but appear more pronounced in LAS 2c. However, the sampling resolution in this subzone is too low to examine adequately the relationship between vegetation changes and burning. Moreover, the limitations to pollen taxonomy of Ericaceae are too imprecise to establish the process with any certainty.

Mire Hydrology and Vegetation Communities

From 270.0 cm, percentage transmission values rise reflect a significant upwards trend in values which persists until 250.0 cm. Initially, this change is accompanied by rising values for both Cyperaceae and *Sphagnum*. However, percentages of both of the taxa are substantially reduced at 270.0 cm, perhaps in response to renewed burning and possibly grazing on the mire. With the reduction in microscopic charcoal from 264.0 cm, both taxa recover and once again mirror the rising percentage transmission values. Pollen preservation is generally good. The peak in corroded grains may be related to evidence for burning after 272.0 cm. Pollen concentrations are generally very low. Peaks in total pollen concentrations coincide with evidence for burning, and may be more closely related to disturbances of the vegetation than changes in the sedimentation associated with mire hydrology. The timing of the inferred shift to wetter conditions took place just after 2,065-1,870 cal BP (120 cal

BC-AD 80). The overlap in chronology with the shift at 292.0 cm highlights the imprecision in the tephrochronology and AMS chronology discussed above.

Percentage transmission values undergo a sustained decline from 250.0 cm. Interpretation of the shift to lower percentage transmission value is complicated. There are no changes in pollen preservation which might reflect drier, more aerobic mire surface conditions. The more sustained peak in total pollen concentrations after 240.0 cm might, however, be a delayed response to the reduction in percentage transmission. Substantial reductions in the abundance of Cyperaceae and *Sphagnum* pollen coincide with the onset of lower percentage transmission values. Percentages of Cyperaceae pollen are further reduced with evidence of burning between 240.0 and 230.0 cm. There are no indications that burning affected pollen preservation as suggested previously. The timing of this inferred shift to drier climate conditions, *ca.* 1,835-1,610 cal BP (cal AD 115-340), is not apparent in other records from northern Scotland (Anderson, 1998). However, it broadly coincides with the so-called 'Roman Optimum', a period of climatic warmth and dryness identified in northern England (Barber *et al.*, 1994) and southern Scotland (Tipping, 1995a).

Dark Age Abandonment

Despite the evidence for drier conditions from 240.0 cm, pollen evidence indicates the catchment was probably abandoned sometime before *ca.* cal AD 430-600. Pollen evidence for any arable activity is largely absent after 234.0 cm, and evidence of local burning is in decline from 230.0 cm. Towards the very end of the subzone, at 216.0 cm, pollen percentages indicate that *Betula* woodland and grassland may have begun to replace *Calluna* heath as the dominant vegetation type.

Lpaz LAS 3a
214.0-168.0cm
Betula-Corylus/Myrica-Poaceae
1520-1350 to 1285-1165 cal BP
cal AD 430-600 to cal AD 665-785

Re-establishment of *Betula* Woodland

Absolute and relative pollen frequencies of *Calluna* continue their declining trend from the previous zone. In LAS 3a, values fluctuate between 10 and 20%, the lowest recorded in the LAS profile. The response of grasses is initially the strongest to the

declining abundance of *Calluna* pollen, as Poaceae pollen rises to 25% by 210.0cm. Poaceae percentages are reduced after this, but remain stable, around 20% for the remainder of the subzone. After a slight delay, at 208.0cm *Betula* percentages undergo a more substantial increase and fluctuate gently between 20 and 25%. Percentages of *Betula* indicate that woodland was probably established locally (*cf.* Bunting, 2002; Huntley & Birks, 1983). Large wood macrosfossils are recorded between 220.0 and 188.0 cm, and although not identified, would seem to support the argument that trees were growing on the mire. The abundance of *Corylus/Myrica* pollen also increases substantially in both relative and absolute terms. This open *Betula* woodland hosted herbs such as *Silene dioica*-type, *Lychnis agrostemma*-type, *Filipendula*, *Hypericum* and Umbellifers. *Alnus* woodland was also briefly re-established, reflected by the increase in pollen percentages and concentrations of this taxon after 196.0 cm. *Salix* percentages indicate it may have been growing locally for a short time, perhaps as a shrub in areas of *Betula* woodland along the mire edge.

LAS 3a reflects a significant period of agricultural abandonment. Microscopic charcoal is almost completely absent from the record between *ca.* cal AD 430-600 to cal AD 665-785. A single grain of cereal type pollen is recorded at 212.0 cm, but arable indicators other than a rare *Papaver*, Caryophyllaceae, Cruciferae, or Chenopodiceae are almost non-existent, and the grain, annulus >10μm which was badly damaged and could represent wild taxa such as *Glyceria fluitans*. Grazing indicators such as *Urtica* and *Plantago lanceolata* also decline, but *Rumex* percentages reach values >2%, and it may have been growing on abandoned agricultural land (*cf.* Behre, 1981).

Mire Hydrology and Vegetation

The period of drier mire surface conditions came to an end by *ca.* cal AD 430-600/1,520-1,350 cal BP. This is recorded in the steep rise in percentage transmission values at 214. 0cm. Pollen preservation is generally improved, except for a single peak of corroded grains at 208.0 cm which does not appear to be significant. Pollen concentrations, declining towards the end of LAS 2c, are further reduced throughout the LAS 3a. Percentages of Cyperaceae increase between 204.0 and 166.0 cm, except for a short period between 188.0 and 184.0 cm. Possibly in relation to the development of the *Betula-Molinia* woodland, the rise in Cyperaceae at 204.0 cm is

characteristic of the abandoned or lightly grazed poor pasture (Rodwell *et al.*, 1991c). Some light grazing may have been maintained, and the high Cyperaceae may indicate invasion by sedges unpalatable to livestock or wild herbivores. Disturbance of wet soils by poaching may also encourage the spread of sedges (Rodwell *et al.*, 1991c), whilst further damaging soil quality. *Sphagnum* maintains its rare presence across the zone boundary, but begins to recover at 204.0 cm with values peaking at 188.0 cm before declining once again. Pollen of herbs such as *Potentilla*-type, *Valeriana* and *Menyanthes* indicate more waterlogged environments, as does the better representation of aquatics such as *Nuphar* and *Potamogeton*.

The increase in percentage transmission values is short-lived. From 208.0 cm, the humification curve reflects a steep decline until 198.0 cm. The lower percentages reflected at 198.0cm persists more or less until the end of the subzone at 166.0cm. These changes are not reflected in either pollen preservation nor pollen concentration data. The increased representation of Cyperaceae and *Sphagnum* follows the decrease in percentage transmission, and such a vegetation change response is the inverse of what would usually be expected from a change to drier conditions. At 200.0cm, the loss-on-ignition curve indicates a short-lived decline in organic content. This does not appear to be related to any significant vegetation changes, but possible changes may be obscured by the lower pollen sampling resolution in LAS 3a. It is not immediately clear why other indicators of mire surface wetness do not seem to be responding to potentially drier conditions. The onset of drier conditions, if that is what the Loch Ascaig core is recording, does not seem to have initiated the re-occupation of the area.

Characteristics of and Mechanisms for the Establishment of Wet *Betula* Woodland

The vegetation changes recorded in LAS 3a bear a resemblance to modern day descriptions of the *Betula pubescens-Molina caerulea* (W4) woodland type. (*cf.* Rodwell *et al.*, 1991a). The vegetation type is can be characteristic of oligotrophic peaty soils, is often found on the margins of blanket mires and owes its development largely to human activity. Overgrazing and mismanagement of *Calluna* heathland may have encouraged its conversion to grassland, as reflected in the increase in the abundance of Poaceae pollen over *Calluna* towards the end of LAS 2c. Subsequent to the spread of grasses, *Betula* invades, usually forming an open canopy of degenerate individuals with Poaceae as the primary component of the field layer. A sub-

community of *Sphagnum* can often be found on wetter, deeper areas of peat, where the water table is low enough to allow *Betula* to grow, but high enough to maintain a carpet of *Sphagnum* mosses. The development of such a sub-community might be reflected by the gradual rise in *Sphagum* percentages between 188.0 and 184.0 cm. *Calluna* and other ericoids are rare in this vegetation type, a characteristic which seems accurately reflected by the pollen record.

The rise in *Corylus/Myrica* pollen is slightly more problematical to interpret. Given the evidence for acidic, nutrient poor, waterlogged conditions it seems unlikely that the substantial rise in the abundance of *Corylus/Myrica* pollen represents *Corylus avellana*, at least exclusively. *Corylus* will not tolerate waterlogging, nor will it tolerate highly acidic substrates (*cf.* Savill, 1991). *Myrica gale* has been observed to form a dense shrub layer of 'leggy' plants in wet *Betula* woodland, where it is often joined by *Salix* (*cf.* Skene *et al.*, 2000). The high pollen concentrations are not characteristic of such a poor pollen producer, but may reflect the abundance of *Myrica gale* in the woodland. It may have spread to the poorer sedge-grasslands around the mire, also accounting for the abundance of its pollen (*cf.* Skene *et al.*, 2000).

The woodland appears to have resisted any succession to *Calluna* heath, or any other successional sequences observed in upland *Betula* woodland (*cf.* Miles, 1988), for nearly 250 years. Although in many areas, stands of *Betula* are usually even aged and live for 60-70 years, stands of Sutherland birchwood have been observed to live significantly longer, up to 150 years or more (McVean & Ratcliffe, 1962). This longevity may partially explain the persistence of the *Betula* woodland. Although the initial stages of this woodland type are promoted by intense grazing, the establishment of *Betula* itself usually requires protection from or the absence of domestic livestock (Rodwell *et al.*, 1991a). The almost complete absence of herbaceous taxa associated with agricultural activity or disturbance and the near absence of charcoal indicates, at the very least, settlements were not located nearby.

The potential influence of wild herbivores on the vegetation should not be dismissed (*cf.* Buckland & Edwards, 1984). Deer will browse most tree and shrub species, exhibiting preferences for *Salix*, *Populus* and *Sorbus*; birch and pine are less preferred, except in winter, or in times of extended snow lie (Hester & Miller, 1995).

Although there is some disagreement in the actual figures, it is generally agreed that stocking densities of <5 deer km^{-1} are necessary for woodland regeneration of broadleaved species (Stewart & Hester, 1998). Heather has been shown to be the preferred food in modern deer populations, although in the summer grasses may form an important component of the diet (Albon & Clutton-Brock, 1988). Grazing by deer, if not too intense, can maintain the structure of the woodland and other vegetation by creating small gaps which would allow the regeneration of *Betula* (*cf.* Mitchell & Kirby, 1990). It is possible, then, that grazing by wild herbivores may have been partially responsible for the maintenance of the *Betula* woodland.

Lpaz LAS 3b
168.0-80.0.cm
Calluna-Betula-Poaceae
1,285-1,165 to ? cal BP?
cal AD 665-785 to ?cal AD?

Re-establishment of Human Activity.

The main feature distinguishing this subzone from LAS 3a is the apparent re-establishment of human activity in the catchment. Fragments of microscopic charcoal are recorded with increasing frequency and are derived mainly from the larger size classes, mostly 60-70 μm and >70 μm. The rising proportions of microscopic charcoal are mirrored by rising *Calluna* percentages. *Rumex* pollen all but disappears from the record after 160.0 cm. Larger fragments of microscopic charcoal continue to be recorded frequently until 100.0 cm, when fragments 20-30 μm become better represented.

Herb taxa associated with disturbance and agricultural activity are recorded infrequently, mainly after 136.0 cm but include *Plantago lanceolata*, *Plantago media/major, Polygala vulgaris*, *Rumex, Urtica, Succisa*, and *Trifolium*-type. A few grains of cereal-type pollen are recorded after 115.0 cm along with a single grain of *Artemesia*, and do not provide a strong indication for the re-establishment of arable activity nearby. *Betula* woodland appears to remain largely unaffected by changes elsewhere in the catchment, and by the influences affecting other vegetation types. Pollen percentages and concentrations indicate that *Alnus* woodland also persisted to a limited extent. Percentages of Cyperaceae pollen are substantially reduced after 154.0

cm, which may be related to evidence for increased burning and the rising abundance of *Calluna* pollen.

From 115.0 cm, areas of former grassland may have been replaced by heathland. *Corylus/Myrica* percentages and concentrations are little change until 115.0 cm. Reductions in the relative and absolute pollen frequencies of this taxon appear to be related to more substantial increase in *Calluna* percentages, additional increases in proportions of microscopic charcoal and further reductions of Cyperaceae. The expansion of burning and grazing on areas occupied by Cyperaceae and *Myrica gale* (see LAS 3a) may have adversely affected the abundance of these taxa. Percentage transmission values begin to increase from 150.0 cm. From 156.0 cm, *Sphagnum* is increasingly well represented. Percentage transmission values peak at 104.0 cm and decline towards the top of the profile at 80.0 cm. Pollen preservation is generally good throughout the subzone. Minor fluctuations in pollen concentrations after 154.0 cm may be related to renewed disturbance of vegetation (*cf.*Aaby, 1988). The absence of any radiocarbon age estimations after 164.0 cm prevents relating any of the changes in LAS 3 to other palaeoecological, proxy climate records or archaeological data.

Summary of Loch Ascaig

The humification record reflects a high degree of palaeohydrological variability during the Late Holocene. Evidence supporting each inferred shift has been discussed in detail in Chapter 6 and the shifts are summarised in Table 6.21. Intra-site comparisons and regional palaeoclimatic inferences are discussed in Chapter 9.

Depth (cm)	Type	Calibrated Radiocarbon Years BP	Calibrate Calendar Years BC/AD
358.0	Wet	4360-4090 (Hekla 4) *TAQ*	2410-2140
340.0	Wet	3940-3700	1990-1750
316.0	Wet	3080-2870 (direct date)	1130-920
292.0	Wet	2160-1940 (Glen Garry) *TAQ*	230 BC-AD 10
272.0	Wet	2065-1870	120 BC- AD 80
250.0	Dry	1835-1610	AD 115-340
214.0	Wet	1520-1350 (direct date)	AD 430-600
208.0	Dry	*ca.* 1490-1320	*ca.* AD 460-630
150.0	Wet	?1240-1050	?AD 710-905

Table 6.2. Summary of palaeohydrological shifts at LAS.

The main feature associated with Late Neolithic/Early Bronze Activity is the simultaneous decline of *Betula* and *Pinus* woodland between *ca.* 4,450 and 4,290 cal BP. The cause of the woodland collapse is not immediately clear from either the pollen record or the humification record. Moreover, it is likely that more than one 'cause' may have been involved. Gap formation, rather than 'stability' is the characteristic feature of woodland, with gaps generated at a variety of spatial scales by wind, pathogens, fire, drought, waterlogging, natural senescence and geomorphological processes (Peterken, 1996).

The initial shift, but modest, rise in percentage transmission values at 358.0 cm may be related to the removal of woodland in the catchment, increasing surface run-off (Swank & Douglas, 1974). However, the timing of the more substantial increase from 354.0 cm, concomitant with the Hekla 4 tephra horizon, implies a relationship with a geional shift to wetter conditions recorded at other northern Scottish sites (Anderson, 1998; Dixon, 1994; Smith, 1998) and across NW Europe (Chapter 2). The pollen record indicates the possible abandonment of the catchment at 358.0cm. However, there does not seem to be an obvious relationship between climate and human impacts registered in the pollen record. Agricultural activities are clearly re-established before percentage transmission values reach their peak and begin to decline.

The role of other factors such as disease, wind and drought in the woodland dynamics is a little more difficult to assess in the palaeo-record. The difficulty with drought is again related to the unquantifiable nature of palaeohydrological reconstructions. Diseases are more likely to affect specific trees, and operate over a longer timescale than, for example, fire (Patterson & Backman, 1988). Disease, unlike fire, cannot be directly inferred from pollen stratigraphic evidence, but again, the concomitant decline of *Betula* argues against it as factor in forest disturbance. If increased oceanicity and gale frequency, hence increased windiness, was an element of regional climate changes inferred *ca.* 5,000-4,000 years BP (Birks, 1988; Gear & Huntley, 1991; Huntley *et al.*, 1998), shallow rooting trees such as *Pinus* may have been vulnerable (Peterken, 1996). The infrequency with which microscopic charcoal is recorded before *ca.* 2200 BC militates against natural fire having a causal role in the disturbance of *Pinus* Loch Ascaig (*cf.* McVean & Ratcliffe, 1962; Peterken, 1996).

Finally, the manipulation of the woodland, or rather natural gaps in the woodland, by humans should not be ignored. Gentle fluctuations in the abundance of tree pollen in the Loch Ascaig sequence may represent short term 'spatially discrete' episodes of abandonment (*cf.* Edwards & Whittington, 1998). For example, if soils were exhausted in one area, activities may have moved to another open area, allowing woodland to regenerate on small spatial scales. The active destruction of woodland around Loch Ascaig by prehistoric farmers is uncertain. Unambiguous palynological evidence for agricultural activity is not recorded until *ca.* 2300 BC, or 362.0 cm. The absence of microscopic charcoal indicates that if farmers were exploiting the woodland, they probably were not employing slash-and-burn techniques to clear areas or even keep them open from scrub (*cf.* Rowley-Conwy, 1981; *sensu* Fairhurst & Taylor, 1971). Early farmers may have contributed to the persistent openness of the woodland by taking advantage of natural gaps created by the formation processes listed above to cultivate small plots, while grazing animals wood have prevented the establishment of seedling trees (*cf.* Görransson, 1986; Brown, 1998). The pattern of woodland destruction recorded prior to *ca.* 2200 BC may be the result of aggregating natural and anthropogenic disturbance episodes, rather than a single, long term event (*cf.* Buckland & Edwards, 1984; Edwards, 1979; Edwards & Whittington, 1998). As people continued to colonise open spaces, preventing regeneration of scrub and woodland, larger and larger areas may have supported predominately treeless vegetation.

From *ca.* 2410-2140 cal BC until *ca.* 1900-1700 cal BC, the agricultural settlements of Loch Ascaig existed in relative equilibrium with the surrounding woodland. Small areas of woodland were cleared as population or economic pressure demanded. Again, the patterns of human interaction with woodland have parallels with Little Rogart, but there the period of equilibrium and stability lasted much longer, around 1000 years (*cf.* Tipping & McCulloch, *unpub*). There, too, woodland remained largely intact, and the process of making small clearances was described by the authors as 'assarting' — the conversion of forest to arable by grubbing up trees and shrubs. While conservation of the woodland at Little Rogart persisted for a millennium, at Loch Ascaig woodland stability may have lasted only 500 years or so. The development and persistence of the *Salix* woodland *ca.* 2060-1870 until 1800-

1630 cal BC is another facet of the apparent balance between the wooded landscape and the agricultural landscape. The distinction is somewhat arbitrary, as these were probably not mutually exclusive entities, but together formed part of the whole of the economic and cultural landscapes of Loch Ascaig.

From *ca.* 1900-1700 cal BC heathland became an increasingly important aspect of the landscape, actively encouraged by the local population. It may be that the perspective of woodland, *ie.* the forest farming economy (*cf.* Göransson, 1986), was altered. The replacement of woodland by open areas such as heathland or grass pasture may have become increasing crucial to increasing the numbers livestock (Gimingham *et al.*, 1983). Investigations of present day agro-pastoral economies have revealed that, according to the perspective of the farmers, wooded areas are considered marginal to the economy, whilst open areas, even if badly degraded by erosion, are considered valuable and economically viable for carrying livestock (van der Leeuw, 2001; McGlade, 1995). The destruction of woodland from *ca.* 1900-1700 cal BC may signal an important shift in both economic practice, as well as cultural perspectives of the landscape. As areas of *Betula* and *Alnus* woodland were cleared to expand open areas for grazing, the capacity of *Corylus avellana* as a valuable crop may have been realised by setting aside areas as coppice woodland. If coppicing *were* undertaken, which it must be stressed can only be speculative based on available evidence, it is another example of how human interference in woodland structure and process became more intrusive, more directed and more managed.

What is more certain is that agricultural activities appear to be increasingly represented by grazing indicators in the pollen record. The more extensive loss of trees from *ca.* 1130-920 cal BC would have altered the hydrological balance of the catchment through reduced evapo-transpiration. Increased run-off in poorly drained areas would have led to gleying of the soils, and in better drained areas, leaching of cations would have reduced soil fertility and led to acidification, particularly around Loch Ascaig, where the parent material is predominately acidic. The heavy burning and grazing which is in evidence would have promoted nutrient depletion and acidification (Legg, 1995), whilst 'poaching' of soils (Batey, 1988) and burning (Malik *et al.*, 1984) would have reduced soil porosity, further encouraging waterlogging and gleying. Increased precipitation would have acted to enhance these

problems. In addition, although litter from *Betula* can maintain or improve soil pH (Miles, 1985), *Calluna* acidifies soils (Gimingham, 1972). The removal of *Betula* and the increasing dominance of *Calluna* from *ca.* 1130-920 cal BC would have contributed to increasingly acidic soil conditions in the catchment. There is evidence that blanket peat may have been spreading in areas of the catchment beyond the mire from *ca.* 230 cal BC- AD 10. Combined *Sphagnum* and *Calluna* percentages reach the values thought to indicate a blanket peat dominated landscape (although not consistently). From the later Iron Age onwards, vegetation communities become less diverse; fewer herb taxa are recorded and trees characteristic of better soils disappear from the record.

The chronology of archaeological settlement at Loch Ascaig is poorly known. While the pollen record provide a good general picture of vegetation change and human impacts, relating these to specific archaeological features and structures in the catchment is impossible. Evidence for past cultivation around Loch Ascaig consists scatters of clearance heaps, some lynchets and areas of cord rig, both near the loch-side settlements and near the settlements at Fernach. One intriguing aspect of the prehistoric settlement archaeology of Loch Ascaig which appears to set it apart from the hut circles of both Kinbrace Hill and Kildonan Lodge, is the presence of 'baffle walls' (Appendix I) situated across the entrances of the huts. Could these be some sort of barrier to keep animals from wandering into houses, as was speculated for the earthen banks at Upper Suisgill (Barclay, 1985), and indicate a very localised economic strategy which emphasised animal husbandry?

Crucially, the period covering later prehistory and the Later Bronze Age is chronologically well constrained in the palaeoenvironmental record. From *ca.* 1900-1700 to *ca.* 230 BC-AD 11 is, with a few exceptions, a period of remarkable human activity. Brief episodes of abandonment are identified *ca.* 1530-1300 cal BC, and later, *ca.* 600-500 cal BC and *ca.* 200-100 cal BC. These occur after shifts to wetter conditions, *ca.* 1990-1750 cal BC (3,940-3,700 cal BP) and *ca.* 1130-920 cal BC (3,080-2,870 cal BP) but a causal link between inferred palaeoclimatic change and settlement occupation is not clearly apparent. Firstly, for most of the period, settlement activity, as recorded by the pollen record, continues largely unabated. Certainly, the concurrence of wet shifts in the humification record and episodes of

abandonment is not a consistent feature of the palaeoenvironmental record of Loch Ascaig. Secondly, the episodes, a few decades at most, represent at most, only a generation or two. These brief episodes, lasting several decades are still quite significant in terms of a human lifetime, and may well represent abandonment or settlement re-location for reasons not motivated by climate or agricultural considerations (*cf.* Tipping & McCulloch, *unpub*). This suggests a change in occupation more closely related to human experience on the scale of everyday life, rather than overarching climatic catastrophe.

The occurrence of a 12th century BC hiatus in settlement is not supported by the pollen data. Palaeohydrological data indicate a shift to wetter conditions *ca.* 1130-920 cal BC, but rather than resulting in the long term abandonment of the catchment, both arable and pastoral activities are very well represented, almost better than any other time in the profile. Consequently, any impact on agricultural activity caused by the Hekla 3 eruption is also rejected. There are no changes which indicate the damage of soils or vegetation in response to profound acid pollution. However, while climate change may not be directly responsible for changes in land use in the catchment or reorganisation of settlement, alteration of the vegetation, climate and pedalogical characteristics would have interacted with each other and influenced the development of edaphic conditions in the catchment.

After *ca.*230 cal BC-cal AD 10 activity is no longer local to the site. It is likely that this overlaps with the construction of the broch at Fernach, approximately 1.5km to the north of the site or at Altanduin *ca.* 2km to the west. On several occasions pastoral activity, represented by burning and increased abundance of *Calluna* pollen, may have expanded nearer to the site. The expansion of pastoral activities may reflect a need for more land as the size of herds was being increased. Alternatively, it may indicate that other sources of food were not sufficient to carry existing herds, requiring the improvement of additional land. A mixed agricultural economy may have remained in place, because arable-type pollen is still recorded, but it is impossible to estimate the scale and exact nature of agricultural production.

From *ca.* cal AD 210-420 there is evidence for sustained burning and management of the heathland closer to Loch Ascaig which persists for *ca.* 90 years. The episode

occurs during a period of drier mire surface conditions, probably reflecting the 'Roman Optimum'. The phase of abandonment *ca.* cal AD 330-560 is the most persistent recorded in the Loch Ascaig profile since the earliest detected activities *ca.* 2500 BC. Admittedly, the sampling resolution is much lower during this period, and short term human impacts on vegetation may not be detected (*cf.* Birks & Birks, 1980). This period of abandonment pre-dated by ca. 100 years the onset of what might be a 'Dark Age' climatic deterioration (*cf.* Blackford & Chambers, 1991) ca. AD 430-600. This absence of human activity in the pollen record persists for ca. 250 years, substantially after evidence for the return to drier conditions ca. AD 460-600. The palaeoecological evidence appears to support the suggestion of a lacuna in settlement during the early first millennium AD (*cf.* RCAHMS, 1993).

Settlement was re-established somewhere in the catchment by *ca.* AD 685-785, during a period of inferred drier climate conditions. From this time, burning is once again recorded, accompanied by the recovery and expansion of *Calluna*. Disturbance indicators are also recorded with increasing frequency. 'Ceannbhaid' is Gaelic for 'birch head', and 'Allt Ceann a'Bheithe' is the 'stream of the birch head'. The place names 'Ceannbhaid' and 'Allt Ceann a'Bheithe' may date from this period. Gaelic speaking peoples first migrated into northern Scotland around this time, the 8th and 9th centuries AD (Omand, 1981) According to the pollen evidence, this area of the Strath still supported a *Betula* woodland. The re-establishment of human activity from *ca.* AD 665-785 might be related to these early Gaelic settlers and the names may have some antiquity because there are certainly are no birch trees on Ceannabhaid today. It is likely to predate Ordnance Survey efforts *ca.* 1801 to provide every feature of the landscape with a Gaelic or English place name (Davies, 2000) since 'Keenvad' appears in a 17th century historical document (Appendix I).

Later settlement activity may be related to the Norse settlement of the area, but there are no dating controls, making it difficult to relate the record of environmental change to the archaeological and historical records. The extrapolated calendar age of the top of the profile is *ca.* AD 1210-1320, around the time when Borrobol and other land in the Strath of Kildonan were granted to Robert Little and his brother, David Sutherland, by the Abbot of Scone, *ca.* AD 1330 (Johnston & Johnston, 1909).

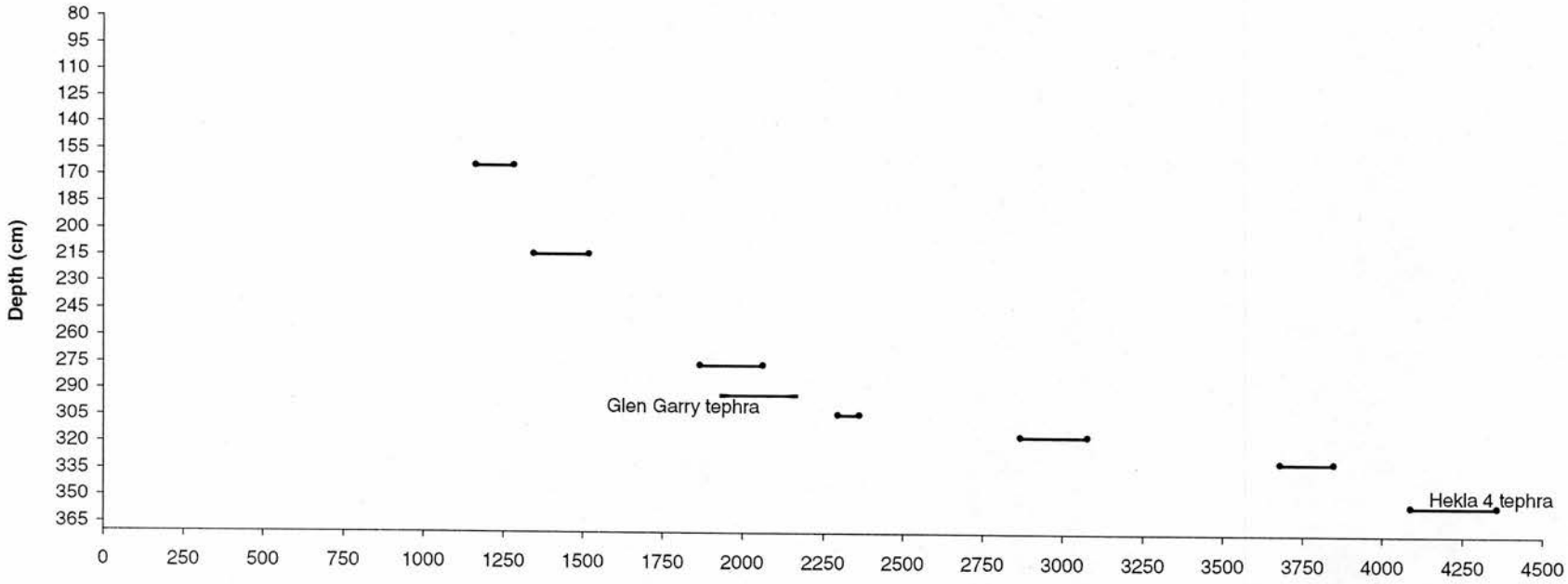


Figure 6.1. Loch Ascaig. Calibrated Calendar Years BP with tephra horizons.

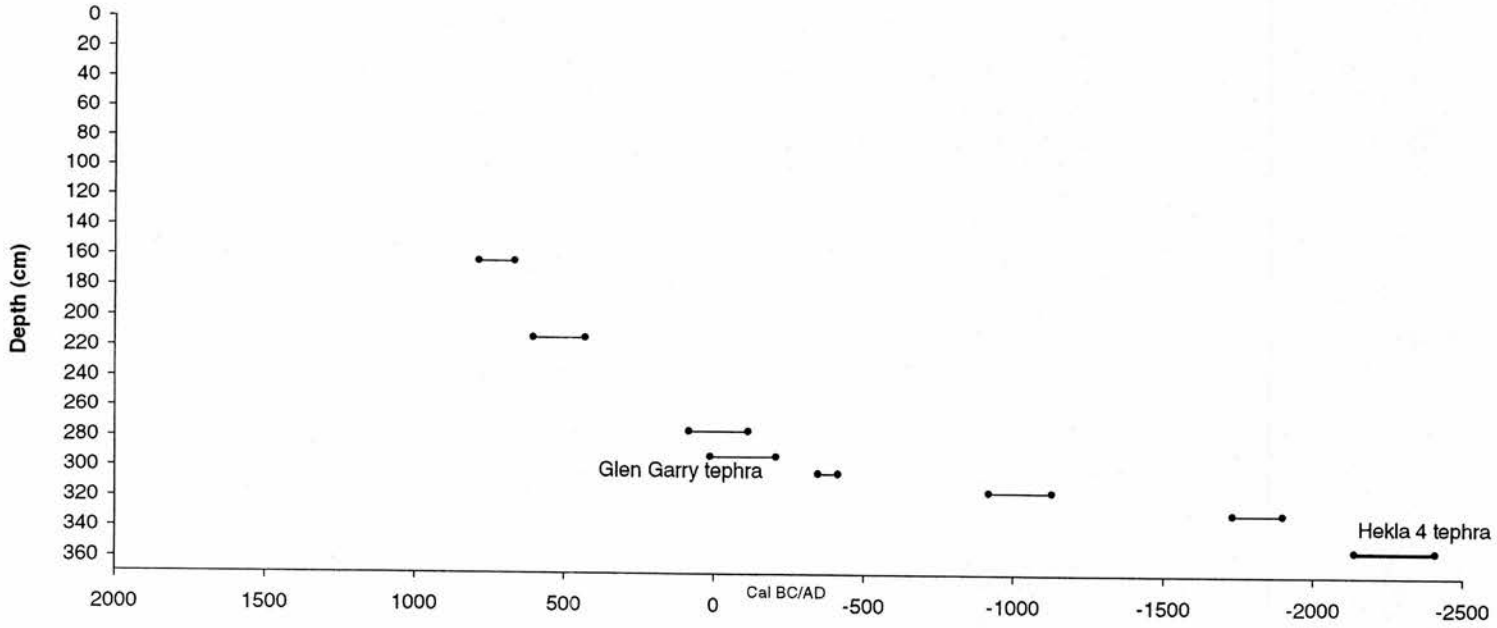


Figure 6.2. Loch Ascaig. Calibrated Calendar Years BC/AD with tephra horizons.

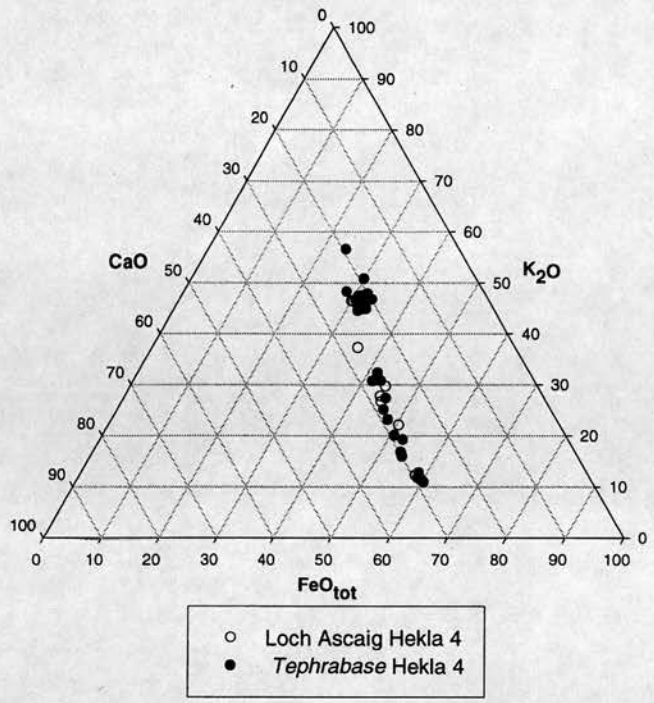


Figure 6.3. Loch Ascaig. Hekla 4 tephra.

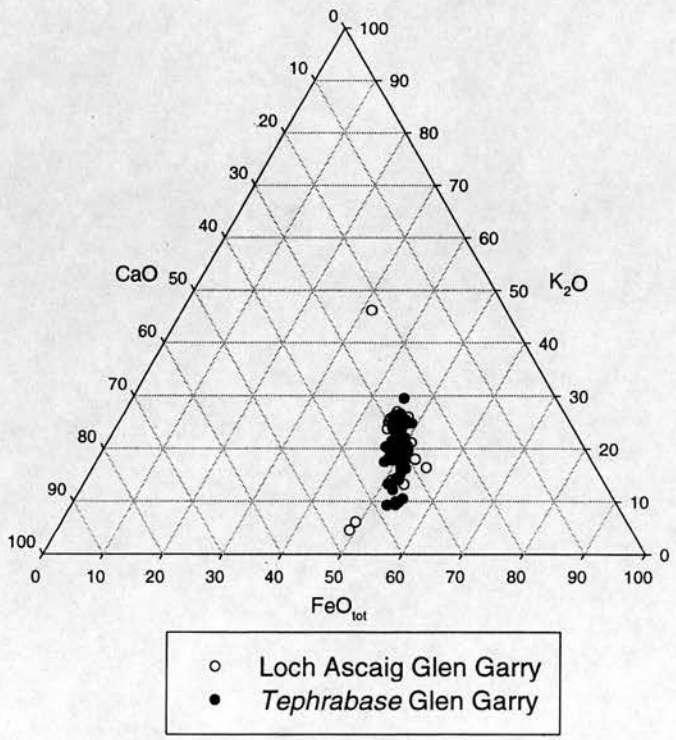
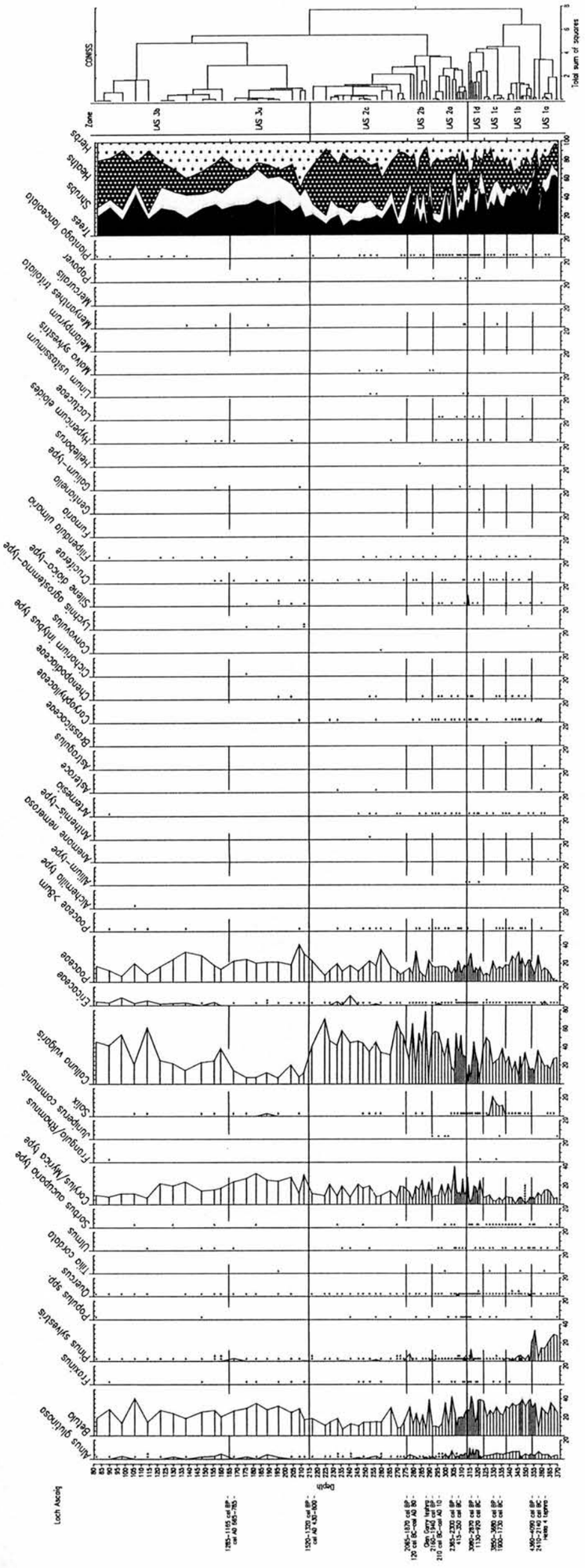


Figure 6.4. Loch Ascaig. Glen Garry tephra.



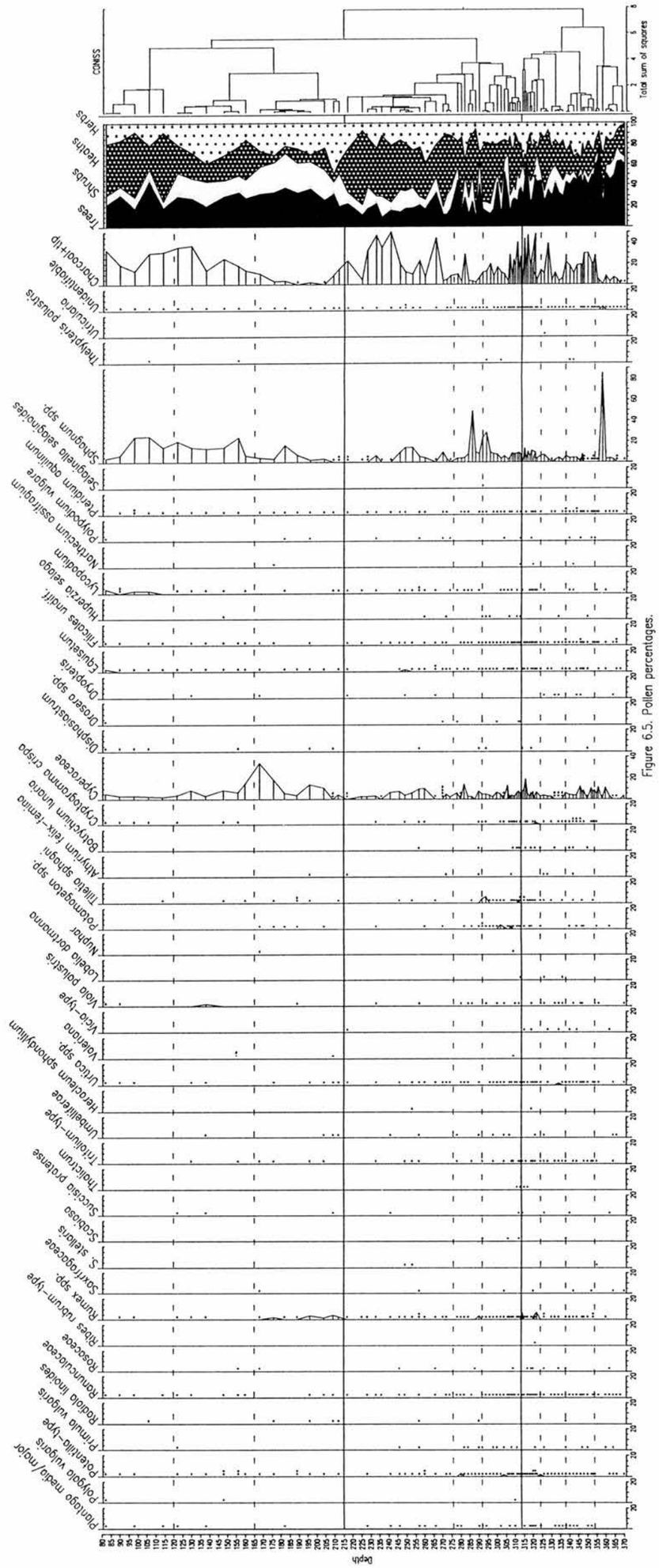


Figure 6.5. Pollen percentages.

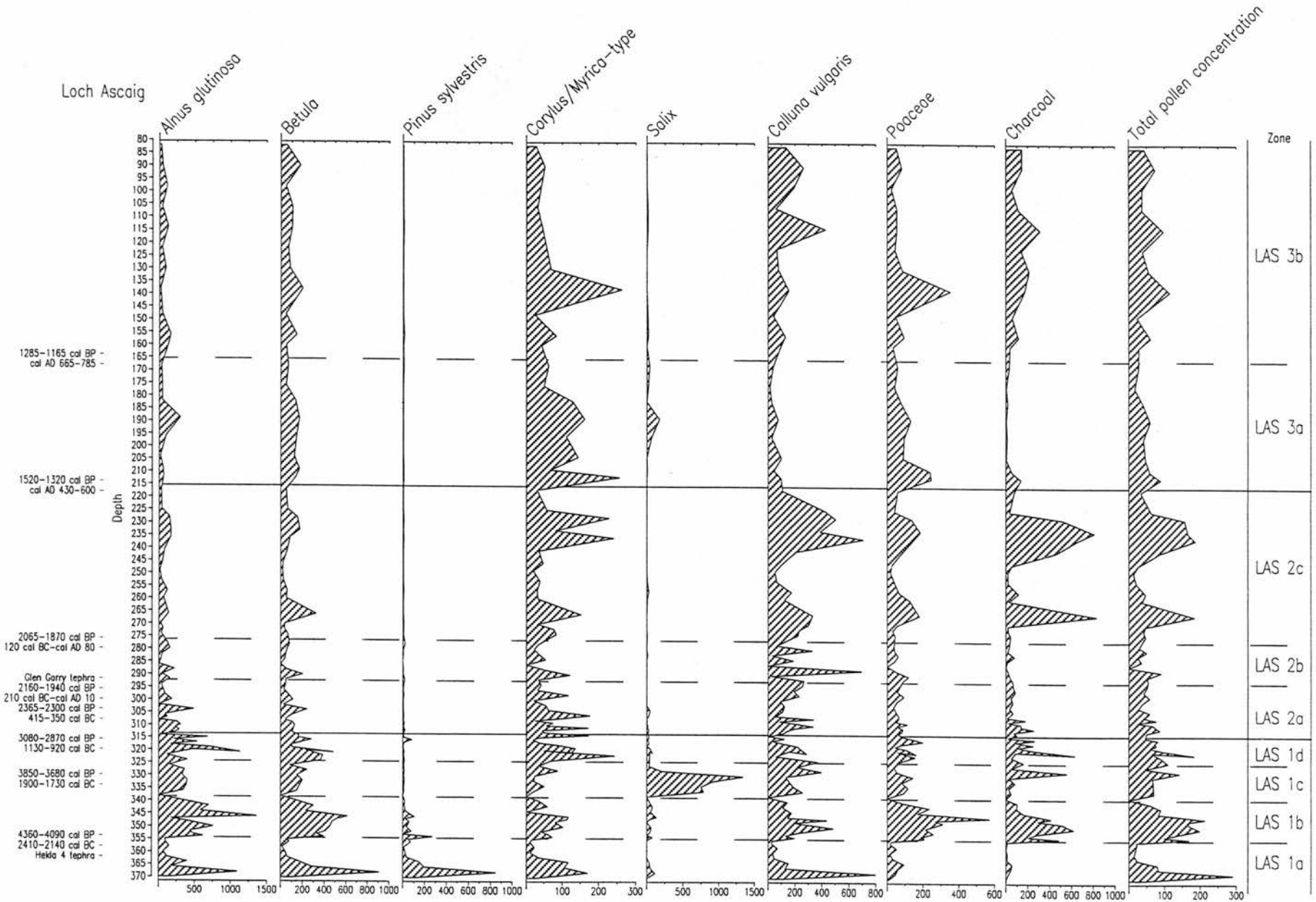


Figure 6.6. Pollen concentrations.

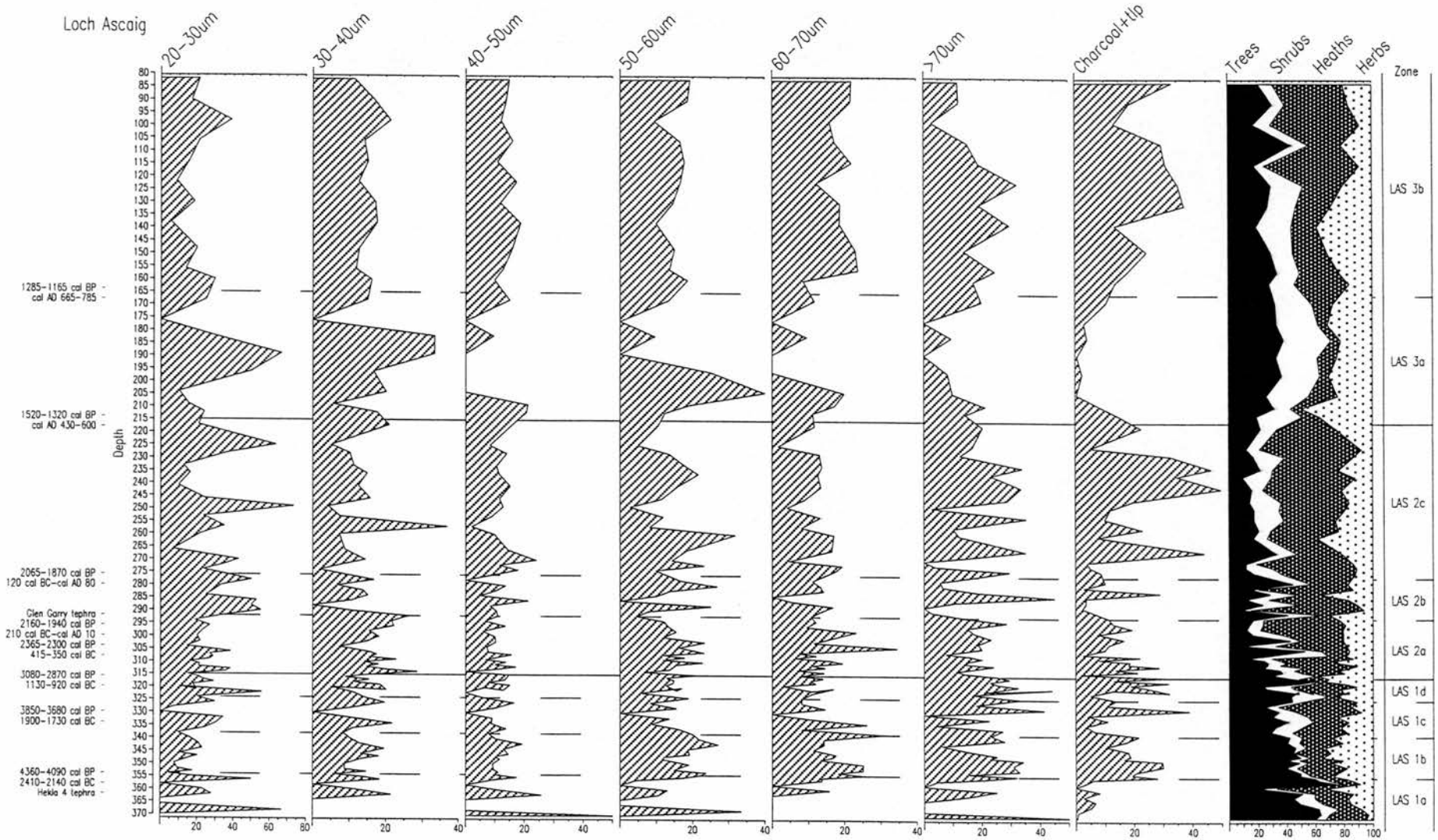


Figure 6.7. Microscopic charcoal.

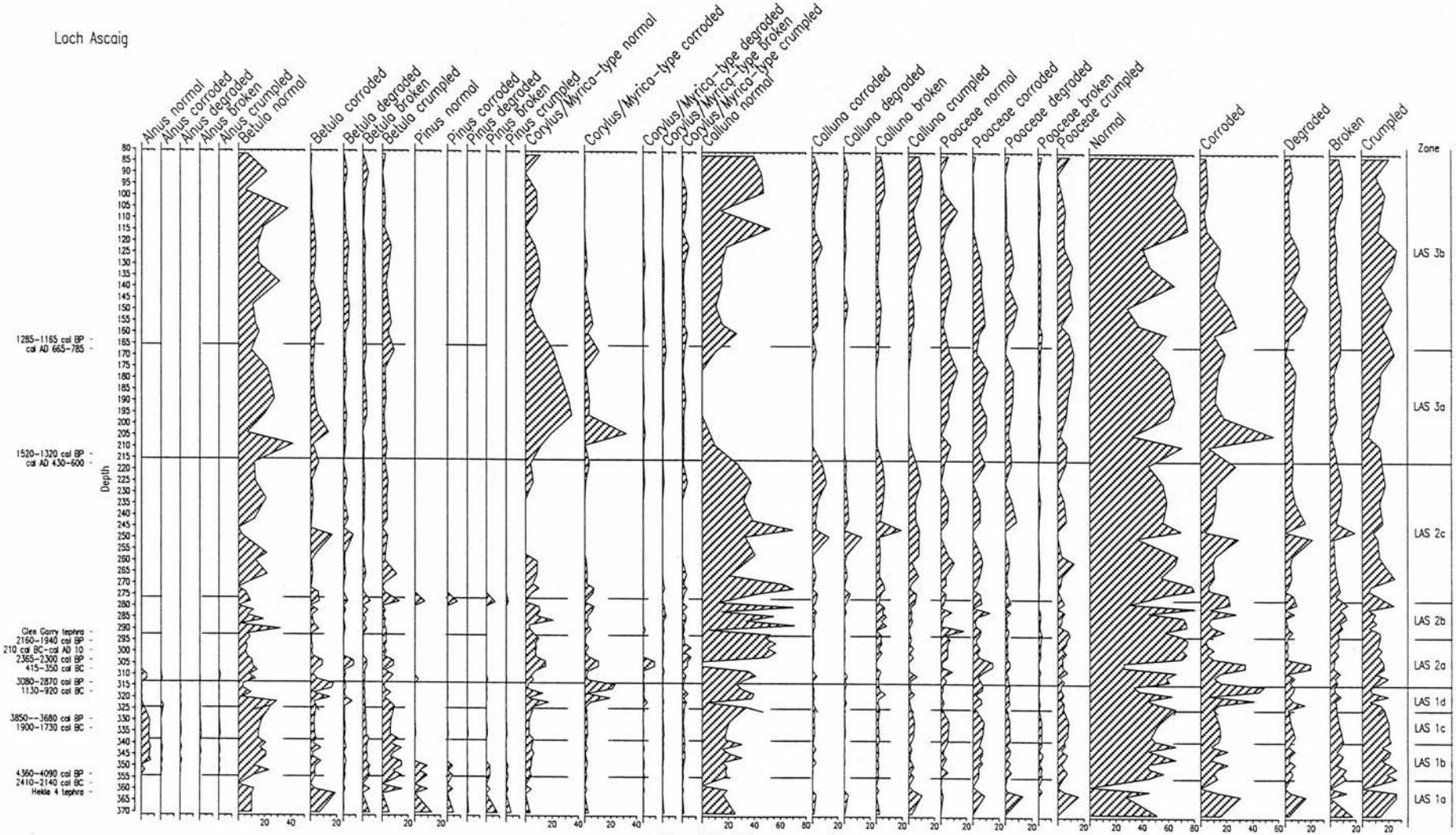


Figure 6.8. Pollen preservation.

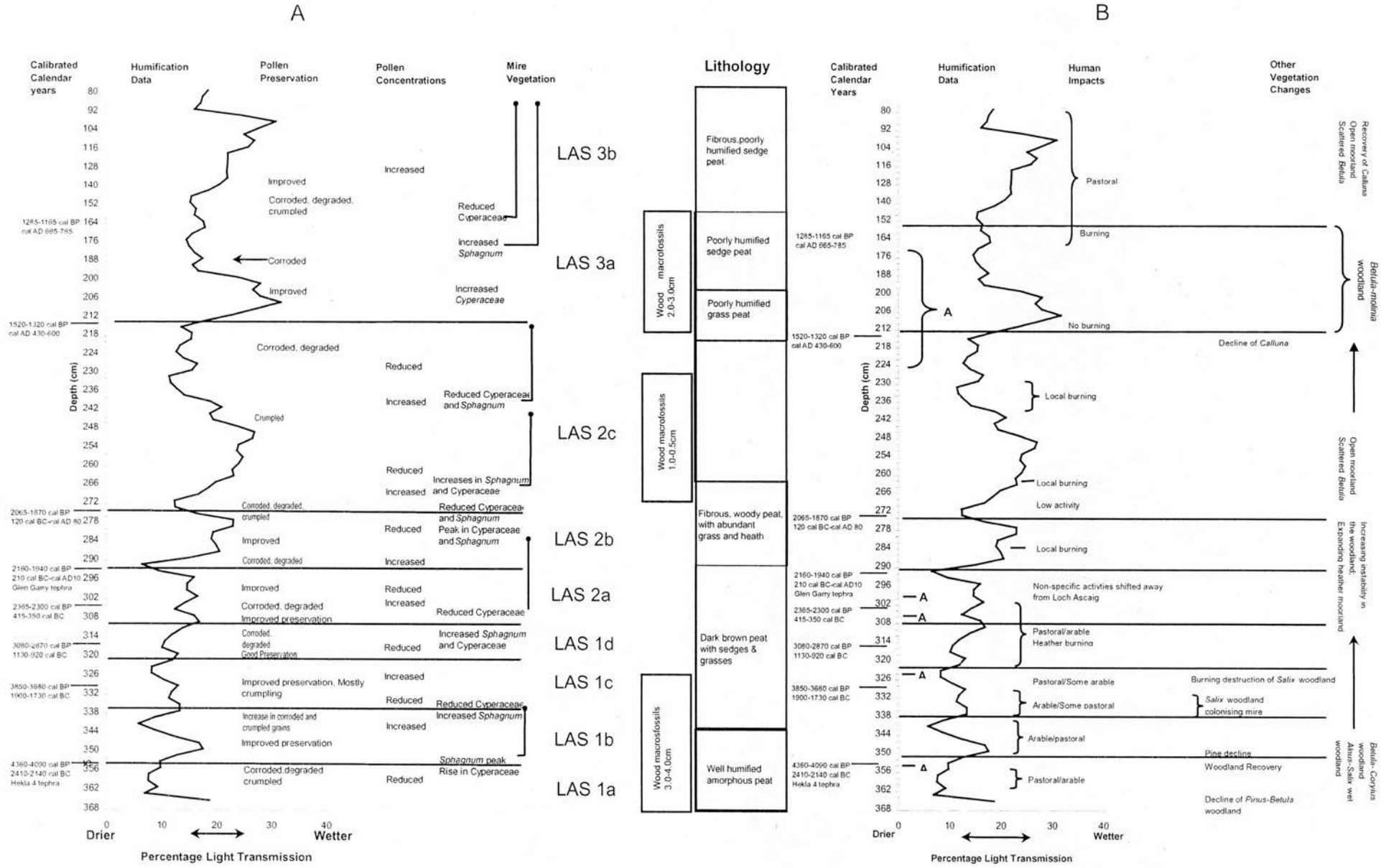


Figure 6.9. Palaeohydrological data, core lithology and vegetation changes for Loch Ascaig. Figure A shows percentage light transmission plotted against depth and age with a qualitative summary of pollen preservation and concentration data and broad changes in mire surface vegetation. Figure B shows palaeohydrological shifts plotted against depth, age with a qualitative summry of human impacts and other vegetation changes.

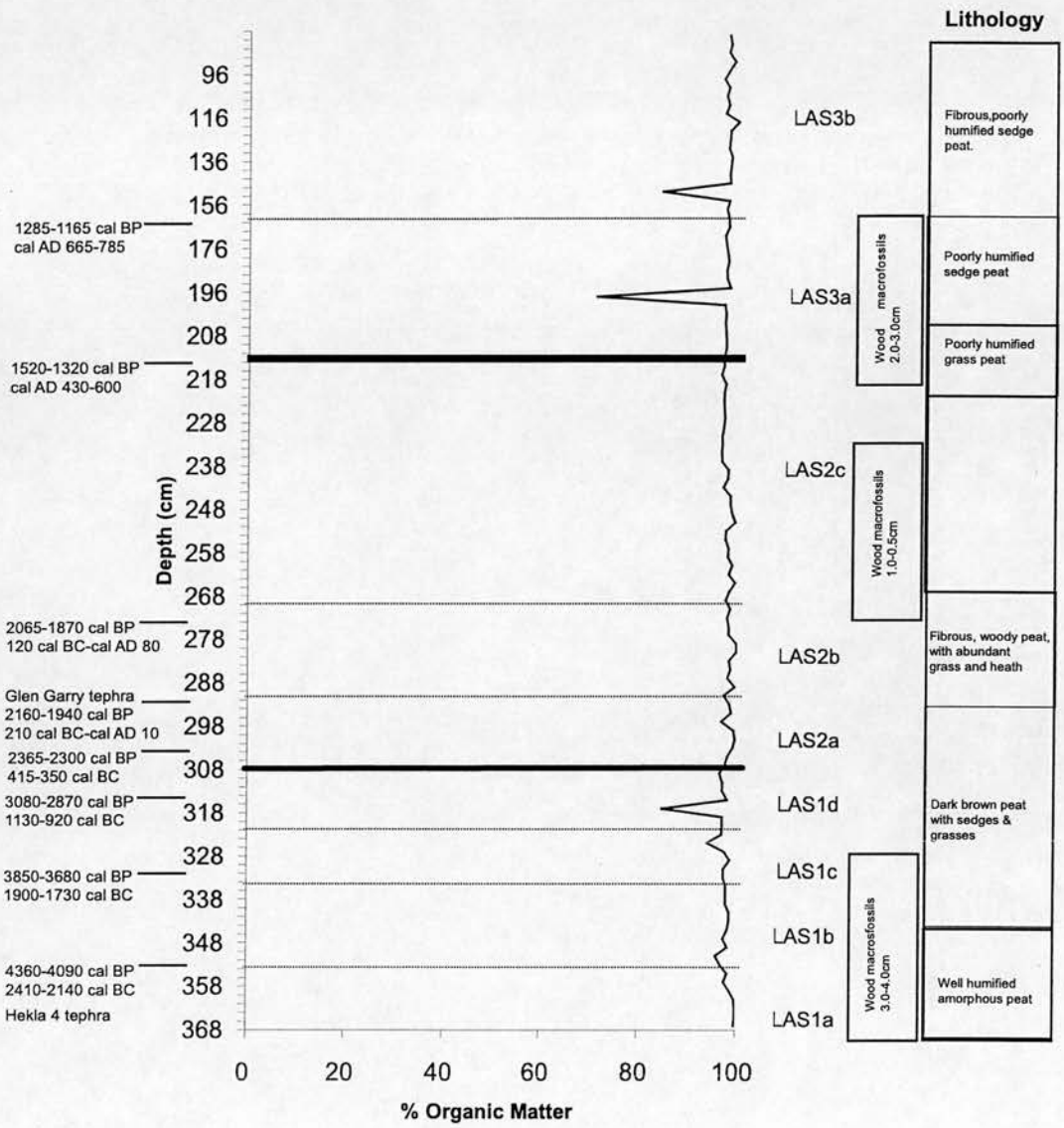


Figure 6.10. Loch Ascaig. Loss-on-ignition.

Chapter 7

Kinbrace Hill

Introduction

This chapter presents the analysis of the pollen and peat-stratigraphic data from Kinbrace Hill, the most 'marginal' site investigated in the study (Figures 4.2 and 5.9). The sampling site is the shedding edge of a saddle mire situated between Kinbrace Hill and Cnoc na Fliuch Airigh ('Hill of the Wet Sheilings) (Figure 5.9). The archaeological evidence from survey (RCAHMS, 1993) is summarised in Appendix II.

Chronology

Publication Code	Sample Identifier	Conventional Radiocarbon Age	$\delta^{13}C_{PDB}$ ‰ ± 0.1	Cal BP 2σ	Cal BC/AD 2σ
AA-51408	KBH-1 191.0cm	3235±40	-27.5	3360-3370	1610-1430 BC
AA-51409	KBH-2 162.0cm	2345±35	-27.5	2460-2310	520-370 BC
AA-51410	KBH-3 132.0cm	1720±35	-27.5	1700-1550	AD 250-400
AA-51411	KBH-4 114.0cm	1355±35	-27.6	1320-1230	AD 630-720

Table 7.1 AMS dates for Kinbrace Hill

Four AMS dates were obtained for the profile and are summarised in Table 7.1. Figures 7.1 and 7.2 shows the 2σ are ranges in calibrated calendar years BP and calibrated calendar years BC/AD. Chronology of the profile is further constrained by the Lairg B tephra at 305.0 cm and the Hekla 4 tephra at 207.0cm. Geochemical data for these two tephra horizons is presented in Figures 7.3 and 7.4. Linear accumulation rates were assumed between each AMS date and/or tephra horizon. Ages of significant changes not directly dated by AMS dates or tephra horizons were interpolated using estimated sedimentation rates between dated horizons.

Pollen- and Peat Stratigraphic Analyses

The late Holocene sequence analysed here commences at 224.0 cm depth. Figure 7.5 presents pollen percentage changes. Pollen concentration data are presented in Figure 7.6 and microscopic charcoal fragments by size classes in Figure 7.7 and pollen preservation in Figure 7.8. Organic content was measured by loss-on-ignition on 2.0cm contiguous samples between 80.0 cm and 220.0 cm and at 4.0 cm intervals between 8.0 cm and 80.0 cm (Figure 7.9). Peat humification on these samples was quantitatively determined by colorimetry and expressed as percentage light transmission (Blackford & Chambers 1993) at the same intervals (Figure 7.10a & b). Descriptions of the core stratigraphy are appended to Figures 7.10a & b.

Lpaz KBH 1a
224.0cm to 206.0cm
Calluna-Pinus-Betula
ca. ?4,615-4,350 to 4,360-4,090 cal BP*
ca. ?2665-2400 to 2410-2140 cal BC

The Late Holocene Woodland of Kinbrace Hill before *ca.* 4,360-4,090 cal BP

Two distinct major vegetation types characterised the landscape around Kinbrace Hill between ?4,615-4,350 and 4,360-4,090 cal BP. The local vegetation was predominately comprised of blanket bog communities. This is primarily reflected in *Calluna* pollen percentages of 40-45%, and percentages of *Sphagnum* at *ca.* 20% before 216.0 cm (*cf.* Fossitt, 1994a) (Figure 7.5). Other taxa characteristic of blanket mire vegetation recorded include *Narthecium ossifragium*, *Drosera*, *Potentilla*-type, *Viola palustris*, *Lycopodium*, Ranunculaceae, as well as some Cyperaceae and grasses and other ericaceous dwarf shrubs. Although certainly the primary feature of the saddle itself, it is unclear how far blanket mire might have extended onto the surrounding slopes, if at all, at this time (*cf.* Fossitt, 1994a). *Calluna* may have colonised the floor of an open *Betula-Pinus* woodland, with *Sphagnum* forming hummocks on the forest floor in wetter areas (*cf.* Rodwell *et al.*, 1991a).

Absolute and relative pollen frequencies of *Betula* and *Pinus* indicate that woodland coexisted with blanket mire vegetation. *Pinus* percentages, although some what unstable, reach and occasionally exceed the 20-25%tlp commonly assumed to

* The age range for the beginning of the interpolated between the Lairg B tephra (5811±60; Pilcher *et al.*, 1996) found at 305.0cm and the Hekla 4 tephra at 207.0cm.

represent local growth (*cf.* Bennett, 1984) (Figure 7.5). *Betula* values fluctuate between 10-25%, indicating a local, if not dominant, presence (*cf.* Huntley & Birks, 1983). *Corylus/Myrica* pollen percentages never exceed 10%. *Corylus avellana* probably formed part of the canopy of an open *Betula* woodland (*cf.* Huntley & Birks, 1983), but conditions around Kinbrace Hill may have been too marginal for *Corylus* to flourish. *Pinus* may have competed successfully with *Betula* on the poorer, less well drained soils on the margins of the mire (*cf.* McVean & Ratcliffe, 1962). With increasing altitude, amixed *Betula-Pinus* woodland would have given way to increasingly mono-dominant stands of *Betula* (McVean & Ratcliffe, 1962). *Populus tremula* and *Sorbus aucuparia* would have been present as scattered individuals in the *Betula-Pinus* woodland (*cf.* Birks, 1988; McVean & Ratcliffe, 1962; Rodwell *et al.*, 1991a).

Areas of transition between open heath and the woodland may have hosted mosses such as *Disphasiastrum*, *Huperzia selago*; ferns, including *Polypodium vulgare,* an epiphyte of *Betula*, *Pteridium* and some grasses. Pollen percentages of *Quercus* are between 2 and 5 % at times indicating that it might have been present nearby, however, its better representation during times of woodland disturbance at 218.0cm might indicate long distance transport from areas of better drained, acidic soils. Rare occurrences of *Ulmus* and *Tilia* pollen indicate long distance transport of these two taxa (*cf.* Pennington *et al.*, 1972). Percentages of *Alnus* <10% indicates a local, but probably meagre presence (*cf.* Huntly & Birks, 1983). *Alnus* is generally undemanding, tolerating soils with a wide-range of nutrient statuses and prefers a high water-table. It does, however it avoids acid peats (Savill, 1991). The predominance of *Calluna* and other acid tolerant trees such as *Betula* and *Pinus* may indicate that *Alnus* had a rather restricted range on the plateau, probably confined to the banks of the two streams draining the saddle with more minerogenic and less acidic sediments. Other taxa such as Cyperaceae and the fern *Athyrium felix-femina* may have been growing in the wet *Alnus* woodland.

Forest Disturbance

From 218.0 cm, there is evidence for disturbance in the *Pinus* woodland. Initially, the reductions in percentages of *Pinus* pollen appear to have stimulated a minimal response from other taxa. There is little change in the representation of non-arboreal

pollen types, perhaps an indication that changes did not affect the woodland edge (*cf.* Edwards, 1979; Edwards & Berridge, 1994). However, the key feature is an abrupt peak in the proportion of microscopic charcoal (Figures 7.5 & 7.7). Fragments belong mainly to the smaller size classes with around 60% measuring less than 50-60μm, also indicating a more distant source. *Betula* appears to have taken advantage of disturbances in the *Pinus* woodland, as pollen percentages and concentrations increase modestly.

Pinus pollen percentages recover somewhat after this, but disturbances are again apparent in the woodland from 214.0cm. This time they appear to be affecting the woodland closer to the mire margin. Reductions in *Pinus* pollen are accompanied by lower *Calluna* values and a sharp reduction in the abundance of *Sphagnum* spores, while Cyperaceae become gradually better represented. This episode is coincident with a larger peak in microscopic charcoal fragments, this time predominantly derived from size classes 50-60 μm and larger (Figure (7.7). Other tree taxa including *Betula* do not appear to be affected by processes influencing the abundance of *Pinus*. *Pinus* pollen appears to recover somewhat between 210.0and 206.0cm, with values over 30%, before declining abruptly across the subzone boundary.

The recovery and increase in percentages of *Pinus* pollen may not necessarily reflect the increasing abundance of the tree in the catchment. Rather, the apparent increase may be an artefact of greater influx of long distance pollen of *Pinus* as well as decreased influx of *Calluna* pollen (*cf.* Charman, 1994). The response of non-arboreal types from 212-210.0 cm indicate that disturbances were closer to the site. Cyperaceae percentages continue to rise, reaching 10% by 206.0 cm. Percentages of grass pollen occasionally exceed 2%. Spores of ferns increase substantially, from rare occurrences to 2-3%. *Pteridium*, a good indicator of disturbance and burning, is also better represented. Openings in the woodland canopy, and particularly near the woodland edge, would have facilitated the transport and deposition of fern spores on the mire (*cf.* Moore, 1988). Herbs such as *Anemone nemorosa* and *Silene dioica*-type would have been growing under a canopy of *Betula*.

Loss-on-ignition values (Figure 7.9) indicate two brief and modest reductions in organic content at 218.0 cm and 208.0 cm. The first may relate to increased run-off

and erosion of mineral sediments after the disturbance of the pinewood recorded at the same depth. The second more substantial peak in mineral matter at 208.0 cm occurs slightly after the initial phases of the second episode of woodland disturbance, but coincides with increased representation of non-arboreal taxa, and the stronger peak in values may also support the inference that disturbances were near by.

Fire in the Late Holocene Woods at Kinbrace Hill

Fire seems the most likely mechanism of forest disturbance at Kinbrace Hill, and these may have been natural, not anthropogenic, fires. Evidence for early Holocene evidence of burning from Cross Lochs, Caithness, only *ca.* 10 km to the north of Kinbrace Hill, has been ascribed to Mesolithic human activity (Charman, 1994). More relevant to the timeframe investigated at Kinbrace Hill, peaks in microscopic charcoal around the time of the pine decline at Cross Lochs were also interpreted as anthropogenic in origin. A 'narrow' approach to Holocene fire ecology, which neglects the importance of fire in the native pinewoods and *Calluna* dominated landscapes of northern Scotland has been criticised (Tipping, 1996). Indeed, it is likely that fire may be integral to the maintenance of pinewoods (Peterken, 1996).

The disturbances in the woodland are not accompanied by any firm palynological indications of human activity. Fires in northern pinewoods are most frequent when the understorey is primarily composed of ericaceous shrubs, as is inferred to be the case at Kinbrace Hill, and most of these fires tend to burn small areas, mostly destroying the undergrowth and occasionally killing individual trees before dying out (Peterken, 1996). This scenario appears to be borne out by the pollen data to some extent. Fluctuations in *Pinus* pollen are accompanied by reductions in *Sphagnum* and *Calluna*, inferred to be growing within the pinewood, as well as on the mire. Relating the changes in the proportions of *Sphagnum* spores to fires affecting the pine is on somewhat tenuous ground as interpretations of *Sphagnum* curves are notoriously problematical (*cf.* Barber, *et al.*, 1994). After the reductions in *Calluna* pollen, the pollen of other types of ericaceous shrubs and grasses are briefly better represented, which frequently happens after the burning of *Calluna* (*cf.* Gill & Groves, 1983).

Mire Palaeohydrology

Percentage transmission values are low for most of KBH 1a, but from 210.0 cm they increase in value, suggesting a shift to wetter mire surface conditions (Figure 10a & b). The improved representation of Cyperaceae pollen does not appear to be related to percentage transmission values in a straightforward way. The initial increase in Cyperaceae pollen may be more closely related to the reduction in arboreal pollen (*cf.* Huntley & Birks, 1983), although peak values near the subzone boundary coincide with higher percentage transmission values. Changing proportions of *Sphagnum* spores also do not appear to be closely related to fluctuations in the percentage transmission curve, showing only a modest increase in percentages after 210.0 cm.

Pollen grains, particularly between 220.0-214.0 cm, reflect some evidence of corrosion and crumpling, possibly associated with more anaerobic surface conditions and compaction of more humified sediments (Figure 6.8). Corroded and degraded grains markedly increase after percentage transmission values begin to rise at 210.0 cm. Pollen concentrations are also quite low for most of the subzone, particularly between 222.0 and 214.0 cm (Figure 6.7). The sediment at these depths is very loose and fibrous, with abundant grass and sedge fragments, which may have contributed to lower pollen concentrations.

Lpaz KBH 1b
206.0-190.0cm
Calluna-Poaceae-*Betula*
ca. 4,150-4,271 cal BP to 3,560-3,370 cal BP
ca. 2200 cal BC to 1610-1425 cal BC

The Pine Decline, Climate Change and Expansion of Human Activity into the Uplands

Percentages of *Pinus* pollen are further reduced to <10% across the subzone boundary. Pollen percentage and concentration data indicate that colonising taxa such as *Betula* and *Corylus/Myrica* did not respond immediately. Rises in *Corylus/Myrica* pollen, to ≥10% from 202.0cm, precede *Betula* pollen increases at 200.0 cm. In the present day, *Corylus avellana* has been observed to precede *Betula* as an early successional taxa in the uplands (Miles, 1988). Increases in *Betula* pollen are restricted to a single peak of 35% at 200.0 cm. *Alnus* values rise smoothly, peaking at

14% at 200.0cm. Pollen of *Salix*, which was probably growing with *Alnus* is better represented the remaining woodland with the increase representation of *Alnus* pollen.

Pollen percentages and concentrations indicate that woodland was increasingly unstable after 200.0 cm. Pollen of *Sorbus,* which like *Betula* is sensitive to grazing, is absent with the decline of *Betula* pollen percentages after 200.0 cm. There is a brief resurgence at 194.0 cm. *Alnus* becomes a rare presence for the rest of KBH 1b, although *Betula* and *Corylus* pollen percentages show signs of recovery. Better representation of *Quercus* coincides with reductions in *Calluna* pollen percentages and concentrations, which probably reflects an improved representation of regional and long distance pollen. *Pteridium* is frequently recorded along with evidence of burning indicated by the microscopic charcoal curve. It is only absent with the recovery of *Betula* pollen percentages at 200.0cm. *Polypodium vulgare* is not recorded with the reduction in woodland, particularly of *Betula,* after 200.0cm. Fern representation is in decline with evidence for the loss of woodland.

Betula, usually an early and aggressive coloniser, appears to have been unable to have taken advantage of the gap left by the demise of *Pinus* on the plateau. Instead, rapidly rising percentages of *Calluna* pollen indicate that it colonised open ground in the wake of the destruction of the pinewood. *Calluna* is usually a rapid invader of cleared pinewood in upland situations (*cf.* Rodwell *et al.*, 1991a). Poaceae pollen is slightly better represented with the near absence of pine pollen from the records. From 204.0 cm, it begins a sustained, if slightly erratic rise to reach 20%tlp at 196.0 cm. Proportions of microscopic charcoal continue the rising trend which began towards the end of KBH 1a. Fragments >50 μm predominate, with approximately one-third of fragments >70 μm. The rise in grass pollen percentages is accompanied by a decline in the abundance of *Calluna* pollen, also from 204.0 cm. Burning and heavy grazing may have been responsible for the encouragement of grassland over heath in some areas.

Human Activity

Records of herbaceous taxa such as *Plantago lanceolata*, *Rumex*, *Succisa pratense, Primula vulgaris, Thalictrum* and *Urtica*, as well as mosses such as *Botrychium lunaria* and *Selaginalla selaginoides* together with increasing abundance of Poaceae

pollen indicate the expansion of grassland. From 200.0 cm, coincident with evidence for reductions in woodland, pollen of herbs usually associated with arable activity is also recorded with growing frequency. These include *Aretemesia*, Caryophyllaceae, Chenopodiaceae, Cruciferae, Lactuceae, Cardueae, Asteraceae, *Radiola* and the fern *Cryptogramma crispa*, the latter two of which are commonly found on broken ground. Between 198.0 and 194.0 cm, when arboreal pollen percentages are at their lowest, several grains of cereal-type pollen are recorded. Despite the evidence for woodland disturbance and cultivation, loss-on-ignition data does not indicate that erosion was a significant problem.

One explanation for the seeming inability of *Betula* to expand initially may indicate that it already occupied most suitable niches in a marginal environment (*cf.* Birks, 1975). A second possible explanation is that grazing may have also suppressed the establishment of woodland or scrub after the decline of *Pinus*. The two episodes of woodland regeneration may indicate brief periods (*ca.* 30 years) of abandonment, but only in certain pockets of landscape where the cessation of burning and grazing in some areas would have allowed the regeneration of woodland (*cf.* Gimingham, 1972, Legg, 1995), because pollen and microscopic charcoal evidence indicates the general maintenance of activities. The large pollen source area of Kinbrace Hill means that the pollen record is a composite of activities and vegetation changes ranging over a wide area.

Mire Communities and Palaeohydrology

The strongest response to reductions in *Pinus* is the expansion of *Calluna* heath, as noted above. Areas of grassy heath on drier land would have hosted *Huperzia selago*. Changes recorded between 197.0 and 194.0cm may reflect a period of particularly high grazing pressure in the catchment. Burning and grazing may have been unfavourable to *Calluna* at times, also affecting the abundance of Cyperaceae. Poaceae pollen percentages and concentrations are at their highest, as are proportions of microscopic charcoal. *Calluna* pollen percentages reflect a steep decline. From 194.0cm, *Sphagnum* percentages increase dramatically, followed by Cyperaceae and may indicate the replacement of areas of heath with Cyperaceae and mosses as a result of abandonment after unfavourable grazing and burning regimes (*cf.* Birse, 1980).

Cyperaceae percentages continue their increasing trend peaking at 25% at 204.0 cm. The decline in the abundance of Cyperaceae pollen after this mirrors both declining percentage transmission values, also from 204.0 cm, as well as increasing anthropogenic pressures on the landscape. *Sphagnum* percentages do not change appreciably, except for a large peak at 194.0 cm, followed by a peak in Cyperaceae at 193.0 cm. *Tilletia spahgni* is better represented with the modest increases in *Sphagnum* after 200.0cm. Mire communities continue to be represented by *Drosera*, *Narthecium ossifragium*, *Potentilla*-type, *Viola palustris*, Ranunculaceae, as well as *Hypericum eloides*. *Potamogeton* is recorded. Areas of wet heath on the mire would have hosted *Lycopodium*. *Potamogeton* is a wind pollinated taxon (*cf.* Stace, 1991), and may indicate pooling on the mire surface, although not necessarily occurring locally. Percentage transmission values peak at 204.0 cm, before declining steadily until 192.0 cm. Pollen preservation generally improves throughout KBH 1b, although there is a modest increase in the proportion of degraded grains. Total pollen concentrations, except for Poaceae and *Calluna* decline from 204.0 cm, although a peak in pollen concentrations accompanies the increases in arboreal pollen at 194.0 cm.

Lpaz KBH1c
190.0-162.0cm
Betula-Corylus/Myrica-Calluna
ca. 3,560-3,370 to 2,460-2,310 cal BP
ca. 1610-1430 to 510-370 cal BC

The Absence of Human Activity on the Upland Plateau

Proportions of microscopic charcoal continue to be depressed across the subzone boundary until 186.0 cm. *Betula* pollen percentages and concentrations continue to rise, before stabilising. Percentages of *Pinus* pollen reach just under 10% for a significant part of KBH 1c. This may represent long distance transport in a more open landscape, but Fossitt (1994b) suggests that percentages as low as 5-10% may indicate nearby growth of *Pinus*. Pollen percentages of *Betula ca.* 20-25% may reflect remnants of woodland in the open landscape. *Corylus/Myrica* percentages are between 10-15%. With the decline and absence of grazing pressure, *Sorbus* was re-established in the *Betula-Corylus* woodland. *Calluna* percentages are reduced to their pre-pine decline values. Management activities such as burning have been

responsible for allowing the periodic expansion of *Calluna* in KBH 1b, but the absence of grazing and management from 194.0 cm means that *Betula* woodland was able to invade areas of heathland.

For *ca.* 900 years, woodland communities—*Betula-Corylus* on better drained soils, *Alnus-Salix* in wetter areas and possibly scattered pines—coexisted with blanket mire communities with little significant change. From 188.0 cm, microscopic charcoal fragments are recorded with increasing frequency, but, until 176.0 cm, any anthropogenic activities do not appear to have impacted the vegetation on the plateau. In contrast to KBH 1b, there is little palynological evidence for human activity on the plateau before *ca.* 1210-920 cal BC. Percentages of Poaceae pollen decline substantially, indicating that areas of grassland were also no longer maintained. Poaceae pollen may represent grasses growing in the open *Betula* woodland (*cf.* Birks, 1973) or as part of the local blanket mire vegetation. Cereal-type pollen is not recorded and arable indicator species are infrequent. *Plantago lanceolata* is not recorded after 176.0 cm. *Botrychium lunaria* is also absent. Other herbaceous taxa associated with grassland or grazing, including *Primula vulgaris*, *Rumex, Thalictrum* and *Urtica* are recorded sporadically along with occasional pollen grains of arable-type herbs. The infrequent and sporadic records of agricultural indicator species may reflect long distance transport.

Later Bronze Age Expansion of Activity into the Uplands

Between 175.0 and 169.0 cm, it appears that human activity expanded into the uplands for a period of around 200 years. Proportions of microscopic charcoal fragments increase, with slightly better representation of larger fragments. Relative and absolute abundances of *Alnus*, *Betula* and *Corylus/Myrica* pollen reflect modest decreases which are accompanied by an equally modest rise in the abundance of *Calluna* pollen. Cyperaceae and *Sphagnum* percentages are also reduced initially, but as the representation of microscopic charcoal fragments returns gradually to the smaller size classes, their representation improves. This might reflect the impact of grazing and burning on the mire as well as surrounding dry land. *Pteridium* is better represented with the rise in microscopic charcoal fragments. The grazing indicator, *Urtica*, becomes better represented after 176.0 cm. There is a modest peak in ferns with indications of woodland disturbance between 176.0 and 169.0 cm. From 176.0

cm, with evidence for some degree of heathland management, arable activity becomes slightly better represented and includes poorly dispersed taxa such as cereal-types and *Artemesia*. These activities were probably not occurring close by, but they do indicate that settlement and/or agricultural practices had, for nearly 200 years during the Later Bronze Age, expanded further into the uplands for the first time since *ca.* 3,360-3,370 cal BP (*ca.* 1610-1410 cal BC). From 169.0 cm *Calluna* percentages decline, Cyperaceae and *Sphagnum* recover, and woodland re-establishes itself, signalling the retreat of activity.

Mire Communities and Palaeohydrology

Intriguingly, better representation of human activity coincides with the start of an upward trend in percentage transmission values, also at 176.0 cm. This precedes the modest reductions in abundance in tree pollen, indicating that the shift is unlikely to have been caused by woodland clearance. This inferred shift to wetter mire surface conditions is accompanied by more frequent records of blanket mire taxa such as *Drosera, Narthecium ossifragium, Valeriana, Viola palustris, Hypericum* and *Lycopodium*. The absence of *Pteridium,* which is intolerant of waterlogging, after 169.0cm may be in response to wetter conditions. The abundance of Cyperaceae and *Sphagnum* pollen may be affected by grazing and burning between 176.0 and 169.0 cm more than mire surface hydrology, although both taxa increase from about 171.0cm, when it is inferred that human activity may have started to wane. Percentage transmission values peak at 172.0 cm, before declining. Pollen preservation improves markedly between 176.0 and 172.0 cm. When percentage transmission values are lower, before 176.0 cm and after 172.0 cm, the proportion of corroded, degraded and crumpled grains rises. Pollen concentrations are low initially, but increase after 170.0 cm.

Lpaz KBH 2a
162.0-134.0cm
Calluna-Cyperaceae-*Sphagnum*
ca. 2,460-2,310 to 1,570-1,410 cal BP
ca. 510-370 cal BC to AD 380-540

Decline of Woodland from the Plateau and the Development of the Blanket peat Dominated Landscape

The relative and absolute pollen frequencies of woodland taxa, *Alnus*, *Betula*, *Corylus/Myrica* and *Pinus*, decline substantially across the zone boundary. The

decline of total tree pollen to ≤25% probably indicates the absence of local tree growth (*cf.* Fossitt, 1994a). *Calluna* percentages rise sharply to 70% or more for most of KBH 2a. Pollen percentages of Cyperaceae and *Sphagnum* each reflect values of 20-40% at various times. Poaceae percentages fluctuate between 10 to 15%. The combined percentages of these taxa meet and substantially exceed the 50-60% believed to reflect extensive blanket peat formation in a catchment (*cf.* Fossitt, 1994a). From *ca.* 520-370 cal BC, woodland was probably absent from the plateau and, in general, the vegetation became less diverse. In areas like Kinbrace Hill where tree growth may be marginal already, slight edaphic changes, anthropogenic pressures and/or climate change may be enough to prevent woodland from regenerating (*cf.* Bunting, 1996).

Some human activity is still registered in the pollen record, as infrequent grains of arable and pastoral herbs, but this is probably derived largely from the regional sources area. However, there are at least two occasions where agricultural activities appear to have expanded a little further in to the uplands between *ca* 2,460-2,310 cal BP (*ca.* 520-270 cal BC) and *ca.* 1700-1550 cal BP (*ca.* cal AD 250-400). Proportions of microscopic charcoal are relatively high throughout KBH 2a, but with fragments spread fairly evenly through the six size classes. At 154.0 cm (260-40 cal BC/2,210-1,990 cal BP), fragments >70 μm increase to 30% of total charcoal accompanied by a marked rise in fragments 50-60 μm, indicating burning was occurring closer to the site. Fragments >70 μm decline, but 50-60 μm and 60-70 μm persist. This is accompanied by modest rises in Poaceae and some reductions in Cyperaceae, as well as even further reductions in *Betula*, *Alnus* and *Corylus/Myrica*. The abundance of *Calluna* pollen appears pretty much unaffected by any human impacts in the catchment. The evidence for burning also coincides with the better representation of corroded and degraded grains. A similar pattern, but accompanied by slightly more prominent vegetation changes, is also recorded between 144.0 cm and 140.0 cm, post-dating an increase in percentage transmission values.

Mire Communities and Palaeohydrology

Percentages transmission values remain unchanged from the previous subzone until 148.0 cm. Here they rise sharply and the higher values persist until 138.0 cm. Pollen preservation is generally very good, although there are notable increases in

corroded/degraded grains at 154.0 cm and between 145.0 and 138.0 cm. Pollen concentrations maintain low values. From 138.0 cm, percentage transmission values are declining. This is not accompanied by a change in pollen concentrations, but pollen preservation is improved. There are no significant changes in mire vegetation directly associated with the change in percentage transmission values. The rise in percentage transmission values post-dates slightly the substantial increase in *Sphagnum* percentages at 152.0 cm. There are further significant increases in *Sphagnum* from 136.0cm, accompanied by better representation of *Lycopodium* which prefers areas of wet heath. *Thelypteris palustris*, a fern which enjoys particularly wet situations (Fitter *et al.*, 1984) is also recorded.

Climate Deterioration and Expansion of Agricultural Activity in the Early First Millennium AD

A second persistent phase of expansion into the plateau area occurred from *ca.* cal AD 50-350 until *ca.* cal AD 250-400, again lasting around 200 years, and again occurring about a century after the inferred shift to wetter climate conditions at 148.0 cm. The episode, briefly mentioned above, is characterised nearby burning of vegetation, inferred from a higher proportion of microscopic charcoal fragments 50-60 μm and > . Unlike earlier in KBH 2a, proportions of *Calluna* pollen appear to be modestly reduced in response to inferred human activity. This is accompanied by the better representation of both grasses and other ericaceous shrubs, albeit short-lived, but this is a pattern of vegetation change that is usually associated with the burning of heather (Giller & Grove, 1983). Proportions of *Sphagnum* and Cyperaceae are both briefly reduced, and were possibly adversely affected by activities which might have impinged on the mire. The substantial increases in corroded/degraded grains are mostly *Calluna*, which is typically a more resilient pollen type. This may also have been influenced by burning on the mire surface.

Lpaz KBH 2b
134.0-60.0cm
Calluna-Betula
ca. 1,570-1,410 to ? cal BP
ca. AD 380-540 to AD ?

Woodland Expansion

Calluna percentages decline substantially across the subzone boundary to under 60%. The apparent decline in the abundance of *Calluna* pollen is relative to a rise in pollen

percentages of *Alnus*, *Betula* and *Corylus/Myrica*. Pollen concentrations of these types do not increase substantially. Although it seems unlikely that this represents the re-establishment of a substantial woodland presence on the plateau directly, elsewhere Fossitt (1994a) has identified a limited local presence of trees with a rise in arboreal pollen from 14% to 30%. Additionally, arboreal pollen percentages of 30% have been recorded in present day open landscapes of northern Scotland within 300 m of woodland 'remnants' (Bunting, 2002). These percentages could reflect anything from open woodland to localised stands (*cf.* Fossitt, 1994a; Bunting, 2002). There is very little evidence for extra-local or local incursions of agricultural activity in KBH 2b. The absence anthropogenic pressures may have allowed woodland to expand further upland. *Betula* may have been able to tolerate wet, acid conditions on the plateau (Rodwell *et al.*, 1991b), but the rises in *Corylus/Myrica* and *Alnus* are likely to reflect the recovery of these taxa away from the plateau due to their intolerance of acid substrates (*cf.* Savil, 1991).

Although it does not appear that human activity was a feature of the upland landscape, the pollen assemblage indicates the continuation of agricultural activities within the larger pollen catchment. The sampling resolution is much lower in KBH 2b, and short-lived incursions further upland may be undetected. Proportions of microscopic charcoal continue to be high. Between 110.0-105.0 cm and again between 80.0-85.0 cm, larger fragments are better represented, but are not related to any significant vegetation changes. They are however accompanied by the first significant change in loss-on-ignition values since KBH1a. Erosion might be related to burning, but higher resolution pollen analyses, as well as better dating controls, are needed to resolve these changes

Mire Communities and Palaeohydrology

From 108.0 cm, percentage transmission values are again increasing. They rise until 100.0 cm, and remain fairly stable before decreasing somewhat after 86.0 cm. Pollen preservation is generally good, although the proportion of corroded and degraded grains increases from 108.0 cm, which seems slightly at odds with the percentage transmission data, and the pollen assemblage. A significant proportion of grains also exhibit crumpling. Pollen concentrations are general low, which suggests faster peat accumulation associated with wetter mire surface conditions. The pollen assemblage

also indicates that conditions on the mire remained relatively wet, especially after 86.0 cm. Proportions of Cyperaceae and *Sphagnum* pollen each remain >20% between 130.0 and 64.0 cm. *Lycopodium,* which prefers areas of wet heath, is increasingly well represented in KBH 2b, particularly after the rise in percentage transmission values, and this taxon remains consistent after the decline of percentage transmission values at 86.0 cm. *Equisetum*, another taxa which prefers wet, marshy conditions, is more frequent from 94.0 cm. As wet acid conditions persisted, the mire vegetation may have become less diverse. Taxa such as *Potentilla*-type, Ranunculaceae, *Drosera, Narthecium ossifragium, Viola palustris* and *Hypericum* are still recorded, and *Epilobium* is recorded for the first time, but records of herbaceous mire taxa are much less frequent.

Lpaz KBH-3
60.0-8.0cm
Calluna-Cyperaceae-*Sphagnum*

This zone represents the disappearance of the last vestiges of 'natural' woodland from the catchment. The rise of *Pinus* pollen after 16.0 cm probably represents 18th and 19th century pine plantations. *Calluna* continues to dominate the vegetation. Percentages reach 80%, and although they appear to drop off towards the end of the zone with the arrival of *Pinus*, concentrations are not only maintained, but increase. *Alnus* pollen largely disappears after 56.0 cm. *Corylus/Myrica* pollen becomes rarer as well. Percentages of *Betula* pollen drop below 10% after 32.0cm. The increase in concentrations and percentages of *Calluna*, Poaceae, other ericaceous species, as well as percentages of Cyperaceae and *Sphagnum*, indicate that the landscape was dominated by blanket mire vegetation (*cf.* Fossitt, 1994a).

Charcoal is well represented throughout the zone, although there is a slight decline after 40.0c m . Most of the fragments are derived from smaller size classes, indicating a larger sources area. Grazing indicators are still recorded, and *Rumex* briefly attains 2%. This herb will exceed values of 1% in treeless habitats and probably indicates that the heath continued to be grazed (*cf.* Huntly & Birks). However, the treeless character of the landscape indicates that that most pollen associated with agricultural activities is probably at least extra-local in origin. Percentage transmission values reflect a steadily increasing trend from the subzone boundary. In general, pollen

preservation is quite good, although some crumpling is apparent. There are minor increases in corrosion associated with minor reductions in percentage transmission values. Pollen concentrations increases after 40.0cm, and reflect the predominance of *Calluna,* Poaceae and other ericaceous shrubs.

Summary of Kinbrace Hill

Tipping (1995) considered uni-directional shifts in the majority of indictors (*eg.*, pollen preservation, total pollen concentrations and percentage light transmission) to be a reliable indication of climatically related wet or dry shifts in ombrotrophic peats. Periods where indicators contradict each other were classified as episodes of complacency, where the peat was neither 'too dry or too wet' (Tipping, 1995). Overlapping 2-sigma age ranges with other regional shifts can also offer some degree of support for wet/dry shifts, although the synchroneity of the shifts cannot be demonstrated with any certainty (*cf.* Anderson, 1998). Compared to the variability reflected and the close correlation consistently observed between the various indicators of mire surface wetness in the Loch Ascaig core (Chapter 6), Kinbrace Hill appears to have been largely 'complacent' during the late Holocene. Based on the best correlation of indicators and overlapping age ranges with regionally identified shifts, four main shifts to wetter conditions are identified in Table 7.2. Although the site is in a position to receive water from the surrounding slopes, there does not appear to be any relationship between episodes of woodland disturbance, where increased surface run-off might be expected to enter the saddle mire, and increases in percentage transmission values.

Identifying dry shifts was complicated by the insensitive nature of the site, made particularly difficult by the lack of quantification associated with percentage transmission values. For example, even though percentage transmission values decline after 204.0 cm accompanied by an increase in corroded grains (Figure 7.8), the vegetation assemblage indicates the mire surface conditions remained relatively wet. A similar situation is also apparent in KBH 2b. It is possible that the mire was overly 'water shedding', and even only the most extreme shifts to wetter conditions were preserved in the mire stratigraphy (*cf.* Charman *et al.*, 1999).

The data suggest a shift to wetter conditions *ca.* 4,150-4,270 cal BP, which correlates well with other regional proxy climate records, both from northern Scotland (Anderson, 1998; Anderson *et al.*, 1998; Dixon, 1994) as well as NW Europe (Chapter 2). The second shift *ca.* 3,160-2,870 overlaps slightly a shift to wetter conditions at the Cross Lochs, *ca.* 10 km north of Kinbrace Hill *ca.* 2,890-2,750 cal BP. It also post dates slightly a shift to wetter conditions in Wester Ross *ca.* 3,340-3,270 cal BP. The apparent discrepancy in timing might be resolved with better dating but might reflect the time transgressive nature of mire response to wetter climate conditions, or the differing responses of the inland, upland mires of Kinbrace and the Cross Lochs to different components of the climate system, than the oceanic peats of Wester Ross. The third shift, *ca* 2,060-1,825 cal BP, is not widely recorded, but does appear in some NW European records (Chapter 2). The timing of the shift is well constrained by the Glen Garry tephra horizon, permitting more precise correlation with a shift to wetter conditions at Loch Ascaig. The timing of the fourth shift, *ca.* 1,285-1,075 cal BP (cal AD 665-875) remains uncertain because of the absence of AMS dates above 114.0 cm. It was felt that it would be reasonable to extrapolate the date over this short distance because the sedimentation rate is unlikely to have altered substantially, but this age estimation is made advisedly.

Depth (cm)	Type	Calibrated Radiocarbon Years BP	Calibrate Calendar Years BC/AD
208.0	Wet	*ca.* 4360-4090	*ca.* 2410-2140 BC
176.0	Wet	*ca.* 3160-2870	*ca.* 1210-920 BC
148.0	Wet	*ca.* 2060-1825	*ca.* 110 BC-AD 125
108.0	Wet	*ca.* 1285-1075	*ca.* AD 665-875

Table 8.2 Summary of local palaeohydrological shifts at KBH.

Before the decline of pine *ca.* 4,360-4090 cal BP, blanket mire and other open *Calluna* rich habitats were already prominent on the plateau. There is no general date for blanket mire inception and spread in the uplands (Birks, 1988). Soil degradation may have promoted its development in areas of NW of Scotland as early as 9,000 BP with no additional influence from climate or people (Birks, 1975). However, in other of NW Scotland, it is inferred that climate change *ca.* 4,000 BP were responsible for

the initiation and/or spread of blanket peat (Pennington *et al.*, 1972). At the Loch of Winless on the east coast, wetter conditions from around 4,500 BP were suggested as causal in the expansion of mire vegetation communities there, where they dominated by 3,000 BP (Peglar, 1979). The initiation and development of *Calluna* rich moorlands near Keiss, Caithness was ascribed to Mesolithic burning, and by 5,000-4,000 BP the landscape was dominated by *Calluna* heath and blanket peat (Robinson, 1987).

Woodland was still an important part of the Kinbrace Hill vegetation before 4,360-4,090 cal BP and even after the decline of *Pinus,* mixed broadleaved woodland persisted as late as *ca* 2,460-2,310 cal BP. In this respect it appears to have more in common with Cross Lochs where mixed woodland was also thought to have persisted much longer (*cf.* Charman, 1994) than in the other areas of northern Scotland mentioned above. Another feature in common between the two sites is the apparent importance of fire in vegetation change prior to the pine decline. At Cross Lochs, this was inferred to be associated with human activities. An anthropogenic source at Kinbrace Hill cannot be entirely ruled out, but based on the subsequent vegetation changes and knowledge about disturbance dynamics in modern day upland pinewoods, natural forest fire seems more likely. Human activity need not been invoked to explain the increase in microscopic charcoal, which may be equally likely to be a result of natural factors at Kinbrace Hill (*cf.* Tipping, 1996). Humification data indicate drier conditions prior to *ca.* 4,360-4,090 cal BP, which is reflected in other northern Scottish sites (*cf.* Anderson, 1998; Charman, 1994; Dixon, 1994) coupled with the vulnerability of northern *Pinus-Calluna* vegetation to fire strongly support a natural source of fire.

The patterns of vegetation change appear to have little in common with the other nearby and also upland site of Upper Suisgill (Andrews *et al.*, 1985). This site is *ca.* 5 km south of Kinbrace Hill. The substantial woodland reduction took place long before that recorded at Cross Lochs, *ca.* 5,320-4,825 cal BP, although comparison cannot be made with potential changes at Kinbrace Hill. The long term record of inferred human impacts culminating with forest regeneration *ca.* 3,650-3,455 cal BP at Upper Suisgill has no parallel at Kinbrace Hill. The episode of minor forest disturbance at Kinbrace Hill *ca.* 2,790-2,460 cal BP only slightly post dates the

inferred expansion of grazing and the inferred shift to wetter conditions. Interestingly, vegetation changes at Upper Suisgill were thought to be related to increased climatic wetness, and may overlap with episodes of erosion which affected the settlement there. Despite the poor chronology of the Upper Suisgill settlement site (Chapter 4), the palaeohydrological reconstructions from both Cross Lochs and Kinbrace Hill offer some support to inferred wetter conditions by Andrews *et al.* (1985) around this time.

Agricultural activity has not consistently been a major feature of the landscape of Kinbrace Hill. This is maybe not surprising given its altitude, *ca.* 240m OD, exposure and the prominence of blanket peat vegetation. At Kinbrace Hill the first unambiguous indicators of human activity do not occur until *ca.* 4,160-3,890 cal BP. What is both surprising and intriguing is the timing of apparent expansion of agricultural activities into upland areas around the mire which are recorded in the pollen profile. The first and most substantial phase of human activity is represented by the expansion of grassland, with perhaps an element of arable activity *ca.* 100 years after the Hekla 4 tephra horizon. This episode persisted until *ca.* 1640-1430 cal BC lasting around 600 years. This upland expansion of agricultural activities post dates slightly the increase in wetter mire surface conditions *ca.* 2410-2140 cal BC.

There is no evidence on palynological grounds for the long term abandonment of agricultural activities in the pollen catchment during the 12th century BC. Although there is evidence for a shift to wetter conditions *ca.* 1210-920 cal BC (3,160-2,870 cal BP), this is followed by a second period of expansion of pastoral activities further into the uplands *ca.* 60-70 years after the increase in percentage transmission values This phase of activity also persists for about 200 years. After a return to lower percentage transmission values, and possibly drier conditions, activity once again seems to have contracted into the lowlands. There is also no evidence for significant vegetation changes which might be caused by acid fallout from the Hekla 3 eruption (*cf.* Grattan & Gilbertson, 1994). It might be expected that the 'critical threshold' for acid inputs would be much lower on Kinbrace Hill compared to Loch Ascaig and Kildonan Lodge, given the evidence from vegetation composition for an acidification. Acid-sensitive taxa like *Alnus* and *Corylus* (*cf.* Savil, 1991) do not exhibit any substantial reductions indicating that they might have been adversely affected. And, as noted

above, human activity continues extra-locally until *ca.* 2,960-2,670 cal BP, and continues to be reflected in the regional pollen rain, probably reflecting settlement in the lowlands.

From *ca.* 2,460-2,310 cal BP, woodland was absent from the plateau and blanket peat became the dominant vegetation type on Kinbrace Hill. This much earlier than the recession of woodland from Upper Suisgill, which occurred *ca.* 1,825-1,920 cal BP (Andrews *et al.*, 1985) Kinbrace Hill is *ca.* 60.0m OD higher in elevation than Upper Suisgill which may have helped to tip the balance against woodland at Kinbrace Hill at an earlier date. Edaphic conditions may have been increasingly marginal to most tree types, except perhaps *Betula*, which is more tolerant of acidic, moist substrates. Increased precipitation would have promoted soil leaching, while burning and grazing would have contributed to nutrient depletion, gleying through soil compaction, episodes of clearance would have also reduced the transpiration and interception of water — all of these may have interacted, making the hold of woodland increasingly tenuous (*cf.* Bunting, 2002).

A third phase of pastoral activity occurred *ca.* 80-100 years after the inferred shift to wetter conditions *ca* 2,060-1,825 cal BP and again, appears to have lasted around 200 years. This is the last time that agricultural activities appear to have expanded significantly into the uplands, although the lower sampling resolution may obscure any short term impacts. The final shift to wetter conditions, at 70.0 cm, the timing of which is cannot be inferred with any certainty because of the lack of chronological constraint, does not appear to have triggered an expansion into upland areas. The regional pollen rain continues to indicate human activities throughout the rest of the profile. There are no clear vegetation shifts which might be associated with the use of the shielings along Kinbrace Burn or near Creagan na Caorach, or that would indicate the establishment of pastoral activities on the plateau, but again these may be obscured in the lower sampling resolution, or be 'swamped' by the pollen originating from blanket peat communities (*cf.* Robinson, 1987; Fossitt, 1994a).

The primary significance of the investigation of the Kinbrace Hill site lies in the demonstration that marginal areas were exploited by the lowland farmers of Kinbrace Hill during prehistory. More importantly, it appears that the marginal upland areas of

Kinbrace Hill were more likely to be exploited for pastoral purposes during periods when it is inferred that climate conditions were cooler and wetter. It is not clear whether these episodes reflect the relocation of settlement into the upland or the implementation of a system of transhumance. The regional pollen component reflects the continuation of activities, probably in the lowlands. Another significant conclusion that can be drawn from the Kinbrace Hill investigation is that the Icelandic volcanic eruption, Hekla 3, had no demonstrable impact on vegetation or the expansion human activity into the uplands. These periods of expansion were not local to mire, although the earliest evidence probably reflects extra-local human activity, perhaps on the surrounding slopes of Kinbrace Hill and/or Cnoc na Fliuch Airgh

Despite successive surveys (RCAMS, 1911, 1993), there appears to be no decisive structural evidence indicating prehistoric settlement on the plateau or adjacent upland areas which can be correlated with the evidence for human impacts in the pollen profile. The apparent lack of settlement may stem from a number of causes. Firstly, due to the large pollen source area of the Kinbrace Hill profile, the spatial extent of the expansion of pastoral activities is unclear. Limited expansion may not have required the implementation of a dynamic settlement strategy. The 'extent' of activities might be resolvable with the investigation of cores from smaller peat filled hollows, thus allowing more localised and specific vegetation reconstructions (*cf* Edwards, 1981; Edwards, 1988; Edwards & McIntosh, 1988). This approach would depend on locating such hollows, which were not apparent from field work for this project. Secondly, this area falls outwith the survey area of the 1991 RCAHMS survey (RCAHMS, 1993); this area may not have been intensively investigated, perhaps due to an expectation that settlement might not be found at such a high elevation in this remote and exposed area of the Strath of Kildonan. Lastly, even during intensive survey, monuments can easily go undetected and the success of surveys is governed by a number of biases inherent in the methodology (Schiffer, 1987). On the west coast of Scotland, it was observed that peat growth and heather effectively hid monuments from sight (Ray & Chamgerlain, 1985).

It is not clear whether the structure near the summit of Kinbrace Hill is genuinely a hut circle (Figure 7.1) (RCAHMS, 1993). It has been speculated that the single huts of Group 1 type might reflect the past existence of a transhumance economy (Cowley,

1998; Halliday, 2000; RCAHMS, 1993). However, the pollen record alone cannot delineate what sort of settlement strategy might be reflected in the periodic expansion of activities. This is highlighted by the observation that changes towards the top of the profile in the pollen record cannot be related with any certainty to the shieling huts along the Kinbrace Burn, although the change in sample interval may be obscuring short term impacts on vegetation associated with shieling use.

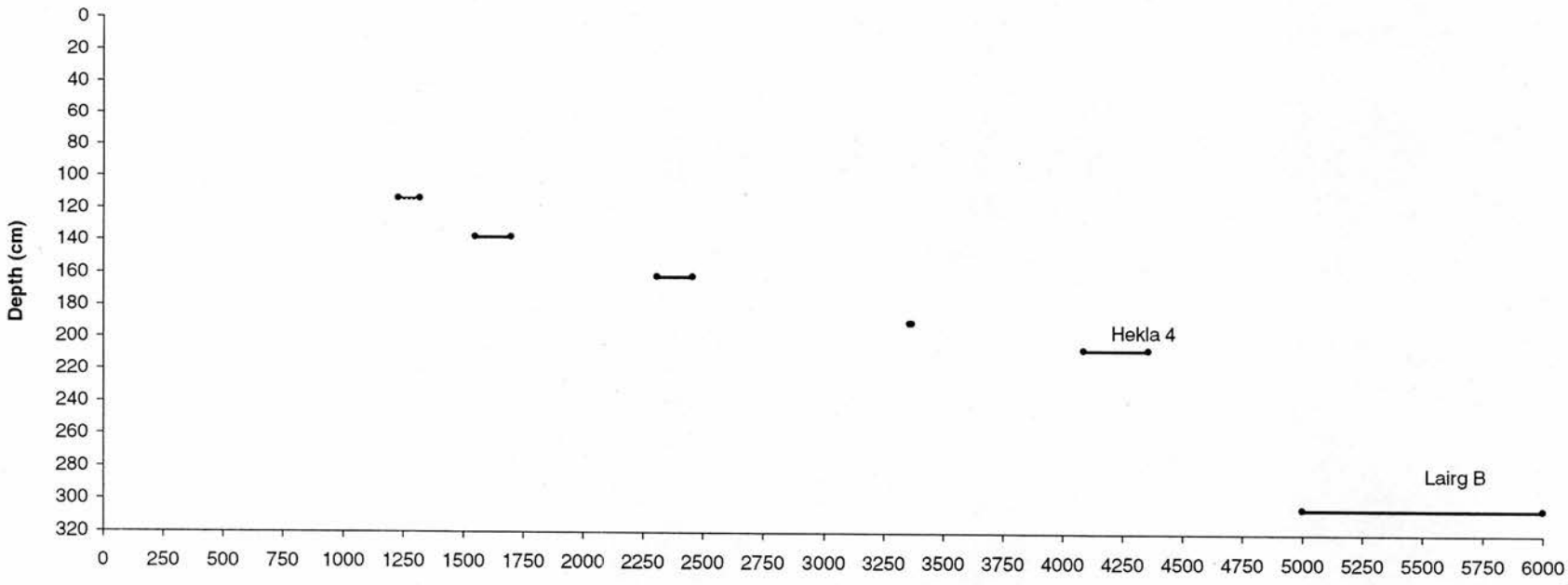


Figure 7.1.Kinbrace Hill. Calibrated Calendar Years BP with tephra horizons.

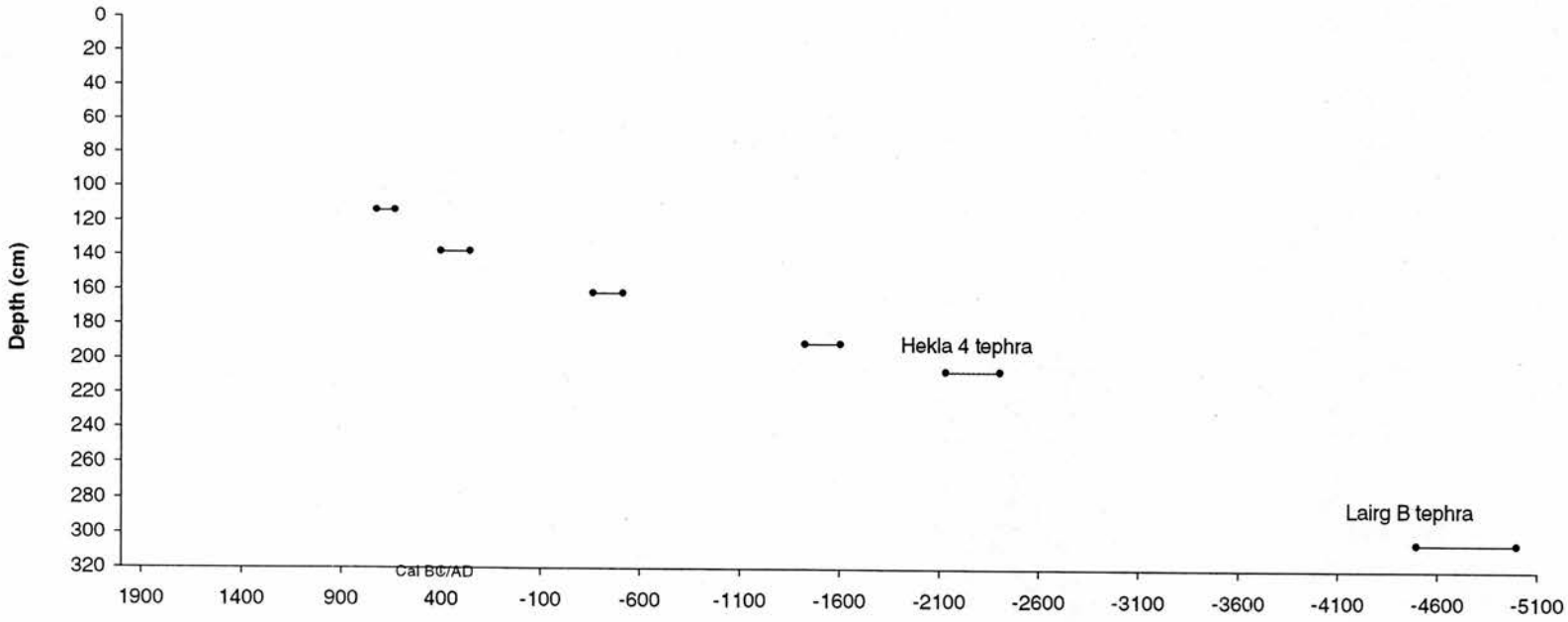


Figure 7.2.Kinbrace Hill. Calibrated Calendar Years BC/AD with tephra horizons.

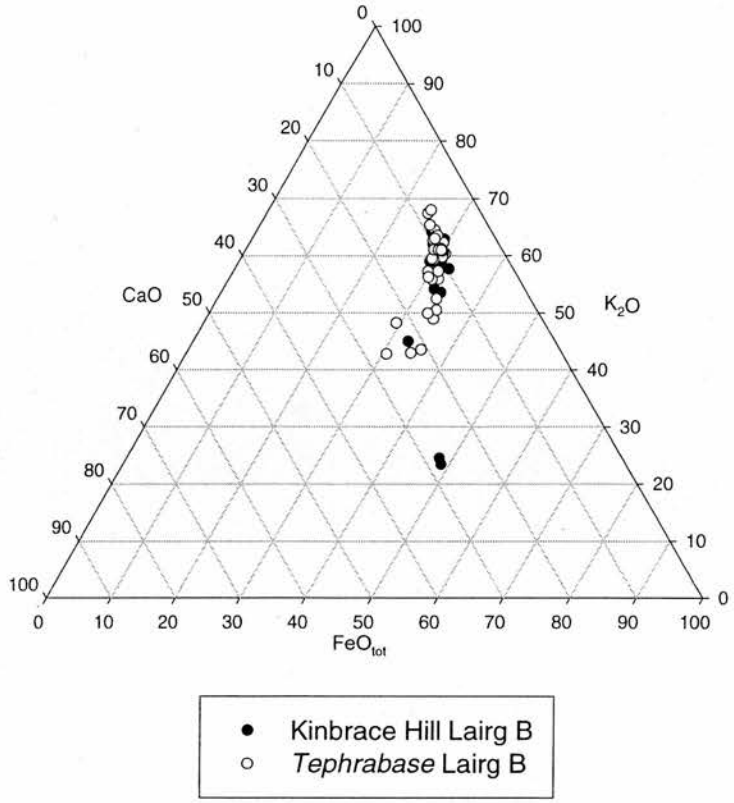


Figure 7.3. Kinbrace Hill. Lairg B tephra.

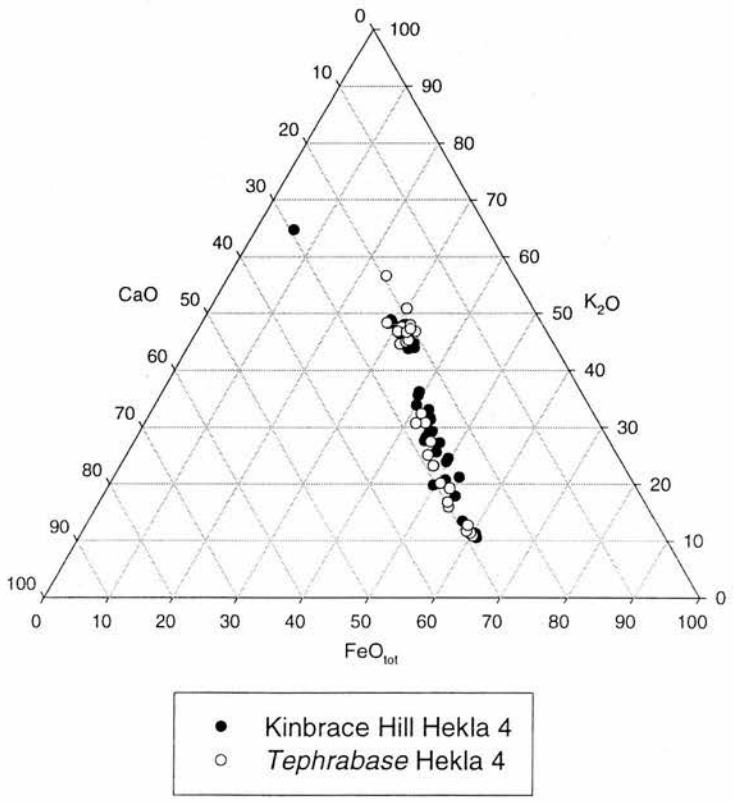


Figure 7.4. Kinbrace Hill. Hekla 4 tephra.

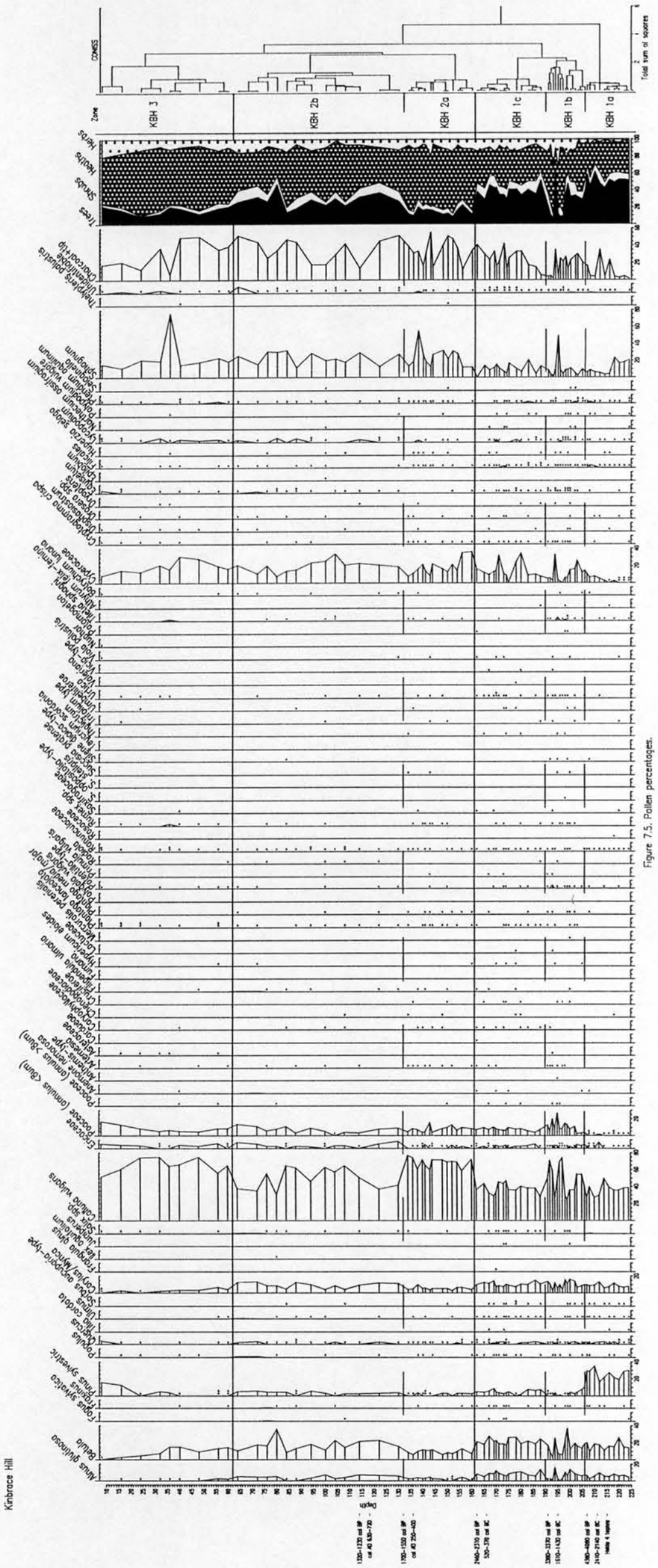


Figure 7.5. Pollen percentages.

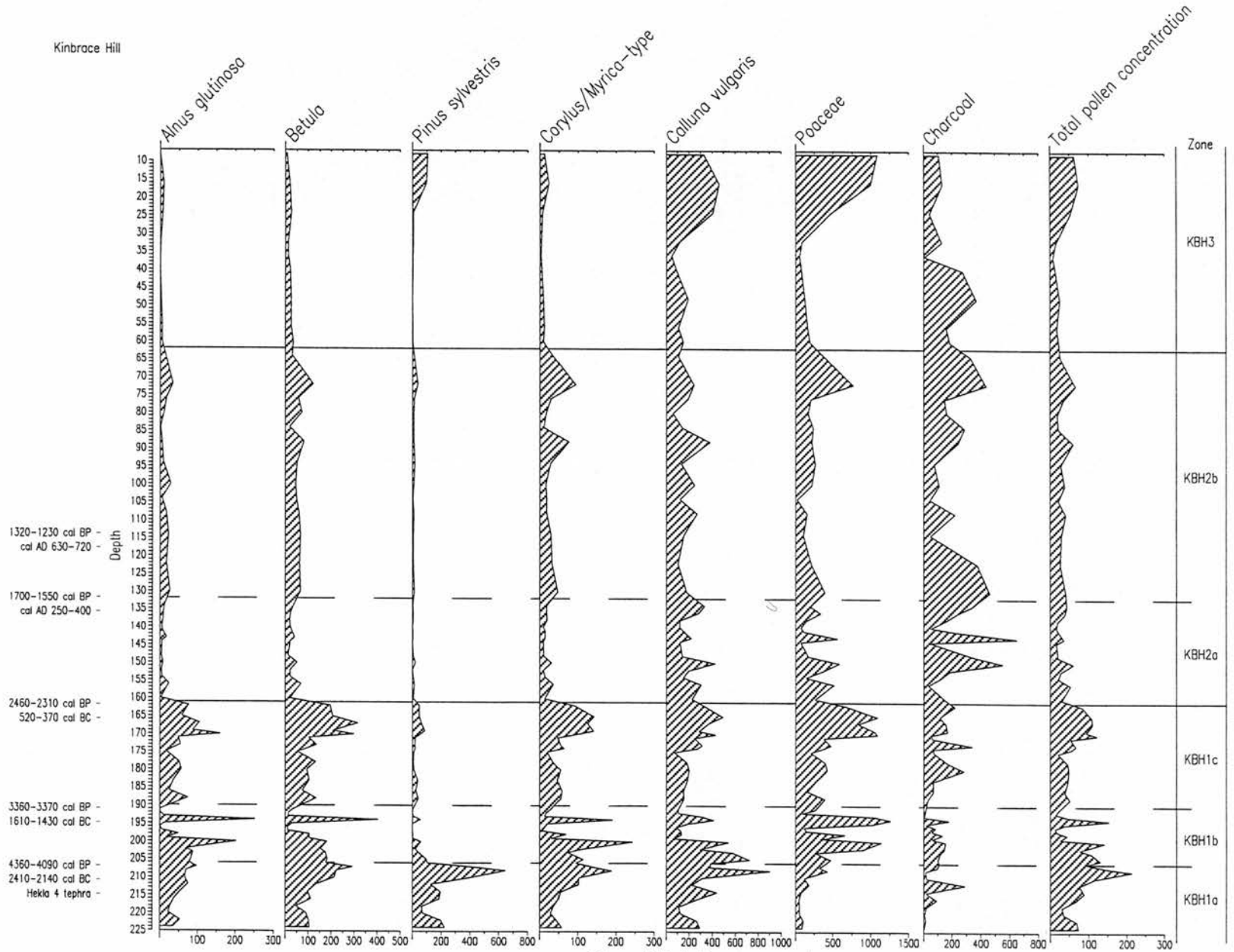


Figure 7.6. Pollen concentrations.

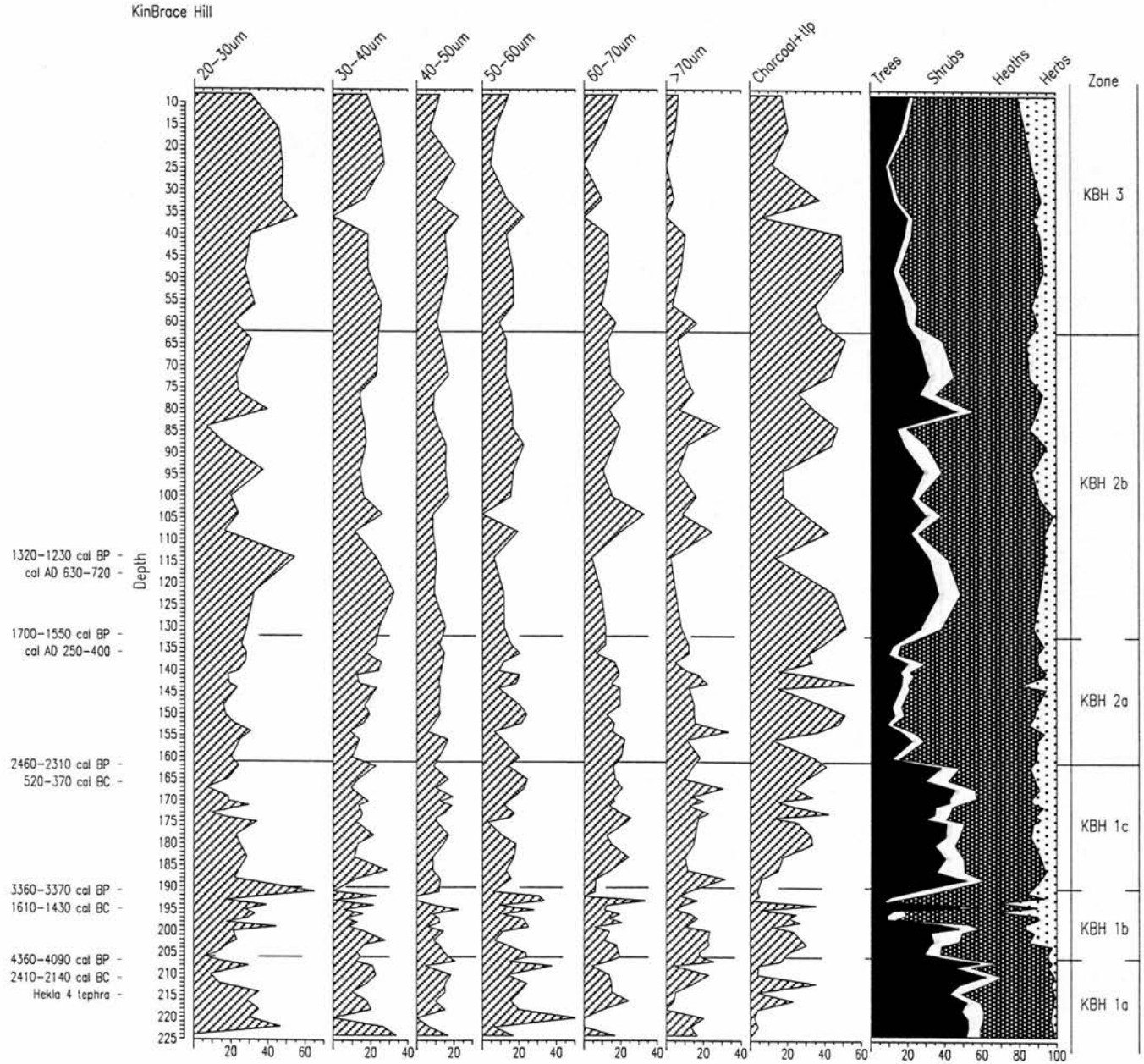


Figure 7.7. Microscopic charcoal.

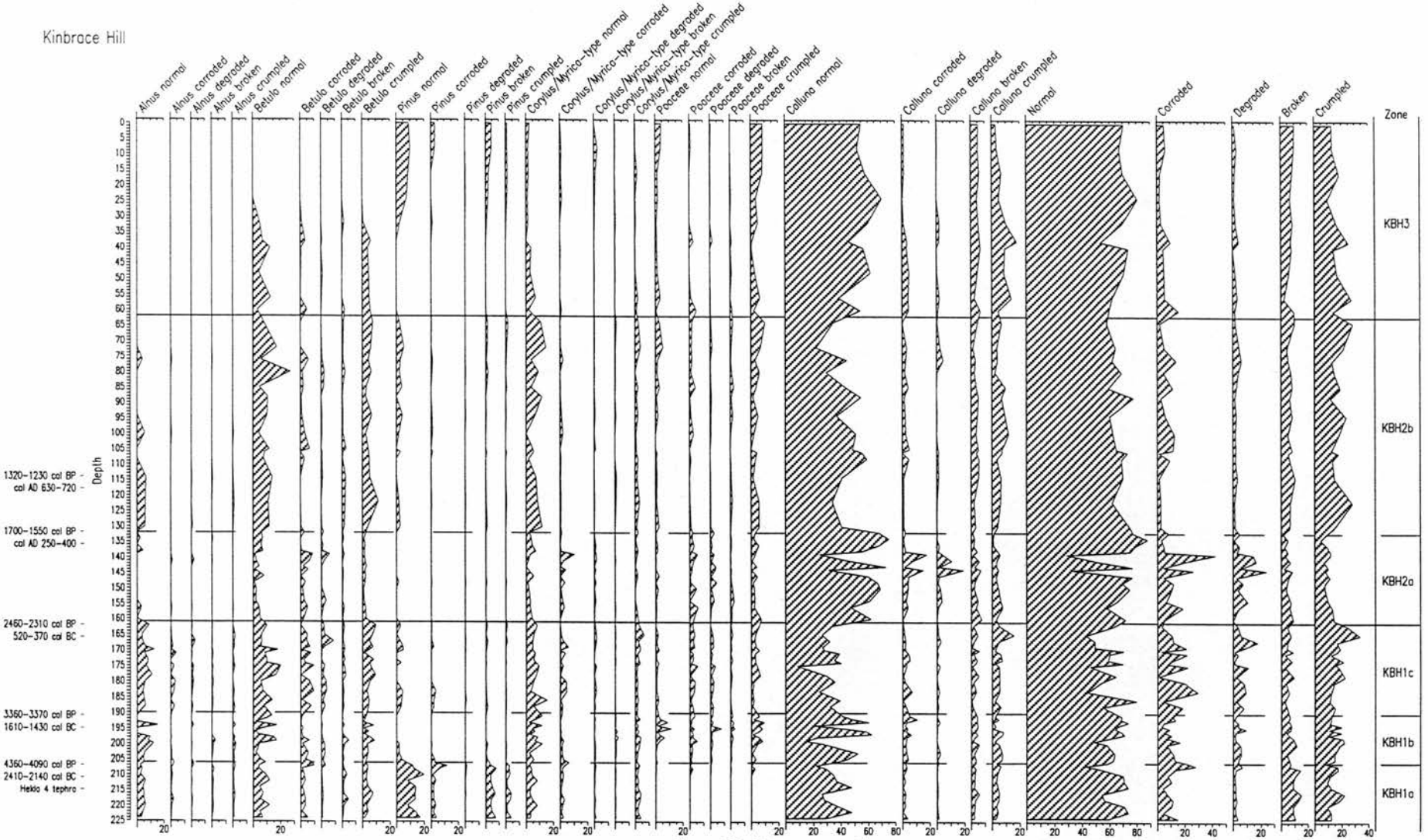


Figure 7.8. Pollen preservation.

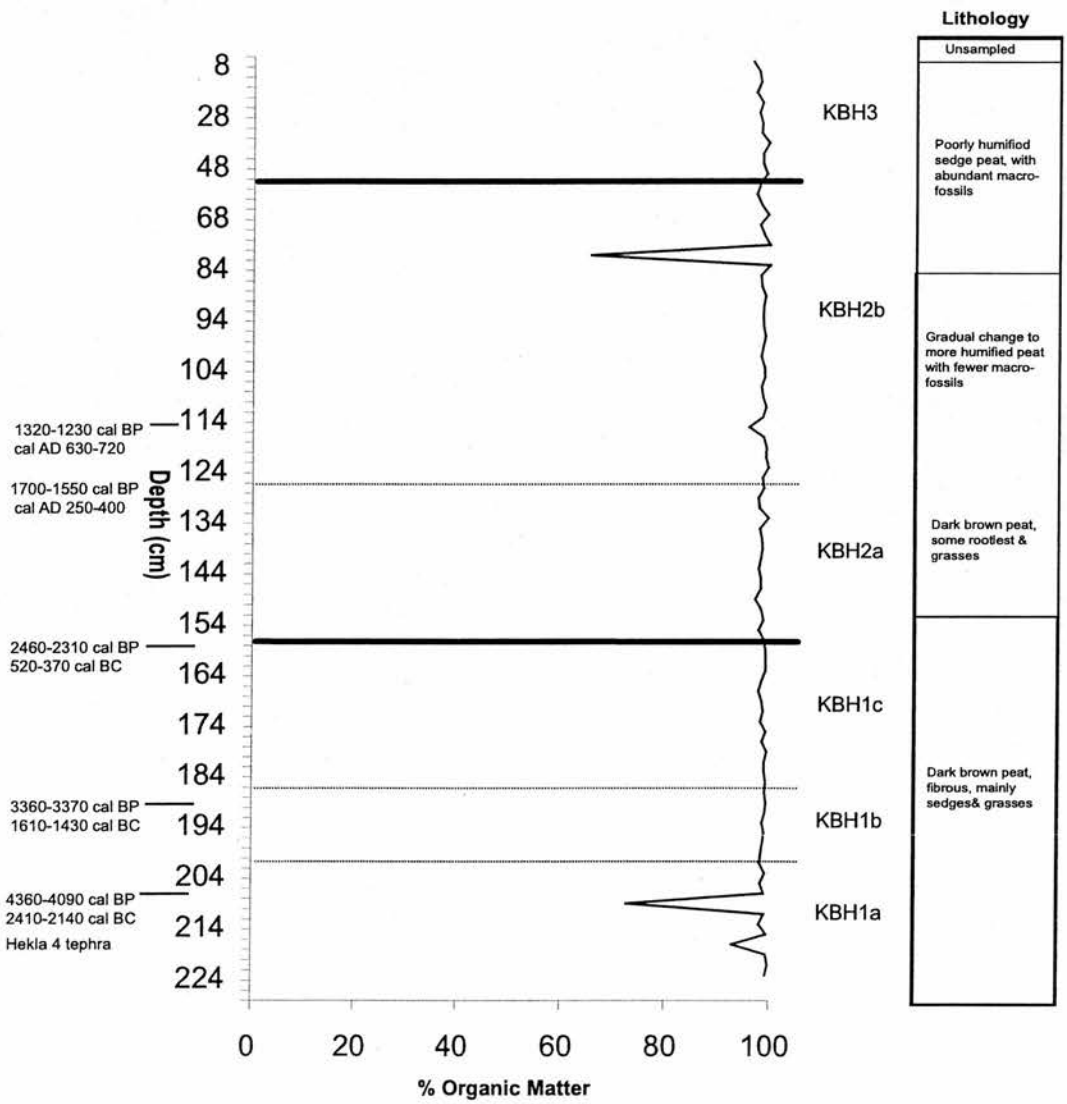


Figure 7.9 Kinbrace Hill. Loss-on-ignition

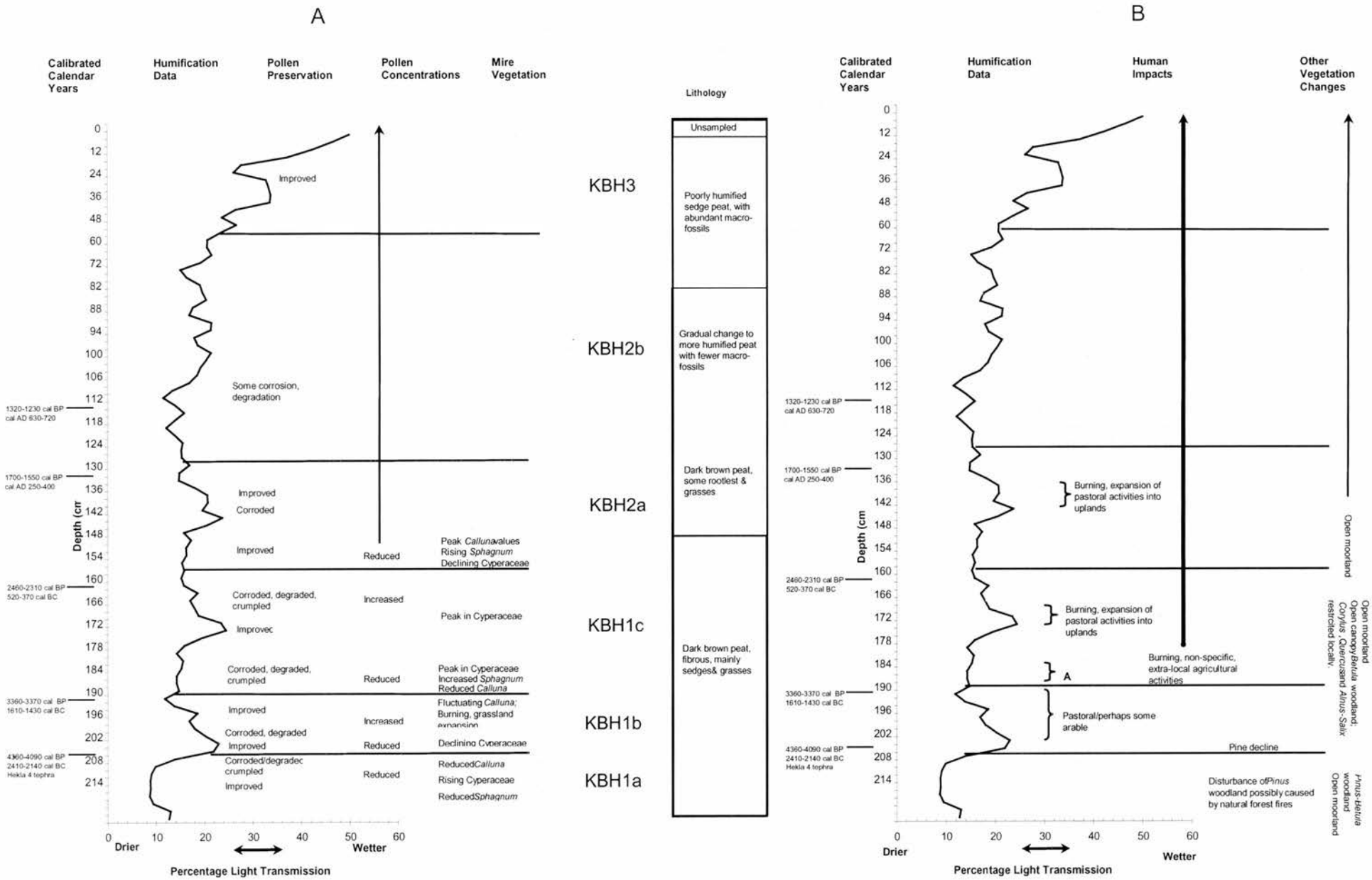


Figure 7.10. Palaeohydrological data, core lithology and vegetation changes for Kinbrace Hill. Figure A shows percentage light transmission plotted against depth and age with a qualitative summary of pollen preservation, concentration data and broad changes in mire surface vegetation. Figure B shows palaeohydrological shifts plotted against depth and age with a qualitative summary of human impacts and other vegetation changes.

Chapter 8

Kildonan Lodge

Introduction

This chapter presents the pollen- and peat-stratigraphic analyses for Kildonan Lodge. The Late Holocene sequence analysed here begins at 80.0 cm. This site was chosen for investigation because of the relative density of Group 1 settlements, which are thought to reflect 'core' areas of more permanent settlement (*cf.* Cowley, 1998; RCAHMS, 1993) (Figure 4.2, 5.7). Archaeological evidence from survey (RCAHMS, 1993) is summarised in Appendix III.

Chronology

Eight AMS dates were obtained for the profile and are summarised in Table 8.1. Figure 8.2 shows the 2σ age ranges calibrated ages in calendar years BP and years BC/AD. Chronology of the profile is further constrained by the Hekla 4 tephra at 65.0 cm (Figure 8.3), the Glen Garry tephra at 55.0cm (Figure 8.4)and a third potential tephra horizon at 14.0 cm. Charman *et al.* (1995) also detected a tephra horizon at 14.0cm in their profile from Kildonan Lodge, and speculated that it might be Hekla 3, but also put forth the alternative hypothesis that it could be tephra from the Laki fissure 1783 eruption. This eruption putatively resulted in crop failure in Shetland and Caithness (Grattan & Gilbertson, 1994; Grattan & Pyatt, 1994). The tephra horizon when analysed in this investigation revealed a distinctly basaltic geochemical signature (Figures 8.5 & 8.6).

The geochemical profile matches that of one of the two Katla eruptions of 1721 or 1755, which are not separable geochemically (Dugmore *pers comm.*). It may be argued that the horizon is more likely to be a result of the 1755 eruption, the more explosive of the two (Dugmore, *pers comm*). There are not currently enough analyses available to make any conclusive statements about the tephra layer. Excessive amounts of diatoms, which are not removed in the organic digestion process, diluted the tephra and made analyses with the EMP difficult. It is hoped that further work can be done to develop this potentially valuable isochrone, using a method of density flotation used to separate tephras from mineral rich sediments (Turney, 1998), which like diatoms, are not

dissolved by the standard solution used for organic sediments. Further development of this horizon, and additional discoveries in other profiles, would provide a valuable chronostratigraphic during a chronological 'blind spot' — near the end of the period where radiometric dating is effective and before the period where Pb^{210} becomes useful.

Publication Code	Sample Identifier	^{14}C Enrichment (%modern±1σ)	Conventional Radiocarbon Age	$\delta^{13}C_{PDB}$ ‰ ± 0.1	Cal BP 2σ	Cal BC/AD 2σ
AA-44950	KLD 5 63.0cm	78.24±0.38	1971±39	-28.4	1995-1860	BC 45-AD 90
AA-44951	KLD 6 60.0cm	78.31±0.37	1964±39	-28.6	1990-1862	BC40-AD 90
AA-44952	KLD 7 50.0cm	81.18±0.41	1675±41	-27.6	1700-1510	AD 255-420
AA-44953	KLD 8 44.0cm	82.51±0.50	1544±49	-28.0	1530-1335	AD 415-640
AA-44954	KLD 9 34.0cm	85.76±0.41	1234±39	-28.2	1260-1065	AD 690-890
AA-44955	KLD 10 18.0cm	91.67±0.65	698±57	-28.1	725-620	AD1225-1330
AA-44956	KLD A 27.0cm	87.17±0.43	1103±40	-27.4	1080-930	AD 870-1020
AA-44957	KLD B 40.0cm	83.78±0.39	1422±38	-28.2	1390-1280	AD 560-670

Table 8.1. AMS dates for Kildonan Lodge

Pollen and Peat Stratigraphic Data

Pollen percentage data is presented in Figure 8.7, pollen concentrations in Figure 8.8, microscopic charcoal size classes in Figure 8.9 and pollen preservation in Figure 8.10 Organic content was measured by loss-on-ignition on 2.0 cm contiguous samples from 80.0 cm and the results are presented in Figure 8.11. Humification data, also measured at 2.0 cm intervals, and expressed as percentage light transmission, are presented in Figure 8.12a, with qualitative descriptions of pollen preservation and concentration data

and vegetation change and Figure 8.12b, with a qualitative summary of human impacts. Sediment descriptions are appended to Figure 8.11 and 8.12.

Lpaz KLD-1a
80.0-65.0 cm
Betula-Pinus-Alnus-Corylus/Myrica
?4,830-4,540 cal BP to 4,360-4,350 cal BP
?2880-2620 cal BC to 2410-2140 cal BC

The Woodland before 4,360-4,090 cal BP

The woodland around Kildonan Lodge was diverse and species rich. Tree pollen percentages fluctuate between 60 and 75% during most of the sub-zone and pollen of non-arboreal types is poorly represented, indicating comparatively closed forest canopy (*cf.* Tinsley & Smith, 1974) (Figure 8.7). Trees may have colonised the mire, as rare wood macrofossils occur between 75.0 and 65.0cm. *Betula* percentages are 20-25% for most of KLD 1, reflecting its dominance of the local woodland (*cf.* Huntley & Birks, 1983). Percentages of *Pinus* reach the 20-25% also thought to reflect its local growth between 78.0 and 74.0 cm, when the woodland was probably co-dominated by these two taxa. The distinction between coniferous and broadleaved woodland can often be blurred in the Highlands (Peterken, 1996), and occasional *Sorbus* and *Populus* may have been scattered throughout (*cf.* McVean & Ratcliffe, 1962).

Betula and *Pinus* may have grown in mixed stands on less fertile, acid soils in the catchment. *Pinus* would have also colonised the crags above the catchment, as well as being established on exposed gravels along the river margins (*cf.* Peterken, 1996). On the better drained, less acid soils in the catchment, *Betula* and *Corylus/Myrica*, assumed to be *Corylus avellana*, would have formed a mixed canopy (*cf.* Huntley & Birks, 1983). Shade-tolerant herbs such as *Anemone nemorosa* may have grown in the woodland nearby; its pollen is poorly dispersed and its presence usually indicates local growth (O'Day, 19??). The deciduous broad-leaved woodland may have also included scattered individuals of *Quercus* and *Ulmus*, with *Quercus* favouring more acidic soils and *Ulmus* more fertile, basic situations.

Alnus values are relatively stable around 15%, indicating that it was an important part of the local vegetation (*cf.* Huntley & Birks, 1983). *Alnus* prefers situations with a relatively high permanent water table, such as along the banks of the Craggie Water and

the Allt na h-airbhe, as well as moist hollows in the woodland (*cf.* Huntley & Birks, 1983). *Salix, Equisetum* and the herb *Filipendula* may have been growing in the wet *Alnus* woodland, along with some types of sedges.

Shade-intolerant *Calluna* may have been confined to the mire surface and openings in the *Pinus-Betula* woodland. Percentage transmission values indicate generally drier mire surface conditions before 78.0 cm (Figure 8.12). Cyperaceae percentages are low, under ≤5%. *Sphagnum* spores rare, although increase slightly with the rising percentage transmission values at 75.0 cm. The low representation of both *Sphagnum* and Cyperaceae may also reflect more extensive woodland cover (*cf.* Huntly & Birks, 1983). Despite the inferred shift to wetter conditions, Cyperaceae percentages decrease, as does the abundance of *Alnus* pollen. Evidence for grazing, burning and cultivation in the catchment becomes more prominent from 68.0 cm. After the increase in percentage transmission values, pollen characteristic of boggier, acidic environments are recorded more frequently including Ranunculaceae, *Hypericum*, *Drosera*, *Potentilla*-type and *Viola palustris*. Pollen concentrations remain steady throughout (Figure 8.8), as do pollen preservation data (Figure 8.10), with the highest proportion of grains exhibiting good preservation. The higher proportions of mechanically damaged grains may reflect sediment compaction of the more humified peat.

Disturbances are apparent in the population of *Pinus*; from 78.0 cm, pollen percentages and concentrations of this taxon decline. *Pinus* appears to be the only tree type affected. The reductions in *Pinus* pollen after 78.0 cm occur prior to the increase in percentage transmission values at 75.0 cm. This disturbance of the pine component may be related to earlier but unresolved disturbance processes implied by the rising pollen percentages of *Pinus* between 80.0 cm and 78.0cm. After the decline of *Pinus* pollen from 78.0 cm, a modest increase pollen percentages and concentrations of *Betula* indicate that some areas of *Pinus* were replaced by *Betula*. The disturbances do not appear to have affected either the wet *Alnus* woodland or areas of *Betula-Corylus* woodland. The lack of response by non- arboreal types, particularly *Calluna*, indicates that these disturbances were probably non-local in nature (*cf.* Edwards, 1979; Edwards & Berridge, 1994). *Pinus* is a shallow rooting species and it may have been easily disturbed by windthrow, or if growing on gravels near the river, it may have been vulnerable to catastrophic

flooding (Peterken, 1996). This may explain why *Pinus* appears to be the only tree type affected, in the absence of evidence for palaeohydrological change or fire.

Loss-on-ignition values indicate that woodland disturbances did not result in increased erosion of minerogenic material into the basin, also indicating disturbances were not local (Figure 8.11). There are no unambiguous indicators of human activity in the catchment before 68.0 cm. A few grains of *Plantago media/major* were recorded before 70.0 cm and *Botrychium lunaria*, a moss commonly found on grassland, was recorded with the Poaceae percentages of 2% at 80.0 cm (Figure 8.9). Microscopic charcoal fragments are also infrequent prior to 68.0 cm. Human activity may have been responsible for disturbances in the woodland, but it might be more likely that Neolithic/Early Bronze Age peoples occupying the catchment would have taken advantage of natural woodland clearances, rather than engaging in purposive clearing by felling (*cf.* Brown, 1998; Goransson, 1986; Rowley-Conwy, 1981).

Reductions in *Alnus* pollen percentages and concentrations after 68.0 cm indicate that woodland in wetter areas was also being affected by this time. *Salix* pollen, which is poorly dispersed, was occasionally recorded with the reduction in *Pinus* pollen, but it disappears with the evidence for disturbance in the wet *Alnus* woodland between 68.0 and 65.0 cm. As *Alnus* and *Pinus* tend to colonise different ecological niches, there is greater likelihood for more directed human interference in woodland after 68.0 cm, as any climatic change would be unlikely to be unfavourable to both *Pinus* and *Alnus* simultaneously. *Alnus*, in particular, would have responded well to the inferred shift to wetter conditions.

From 68.0 cm, disturbances appear to be affecting woodland closer to the site as representation of non-tree type pollen increases. Poaceae in particular begins to increase and achieves values of 15% before the end of the zone. The frequency and diversity of herb taxa also increases substantially. These include types associated with pastoral activities such as *Plantago lanceolata, Anthemis*-type and *Urtica*. Other taxa associated with grassland include the moss *Botrychium lunaria* which is once again recorded. *Polygala vulgaris*, an indicator of 'ancient' grassland (*cf.* Grime *et al.*, 1990) is recorded, and may indicate that pastureland and grazing have been present in the catchment for sometime prior to 68.0 cm before being detected. *Pteridium aquilinum* is

also apparent from 70.0 cm, and is usually associated with gaps in woodland cover as well as burning. With the reduction of woodland there are also indicators of arable activities in the catchment as well. Cereal-type pollen is recorded at 66.0 and 65.0 cm along with herbs such as Chenopodicaeae and Caryophyllaceae, although arable herbs such as *Artemesia* and Asteraceae were apparent from 68.0 cm. From 68.0 cm, proportions of microscopic charcoal fragments are also rising, although still relatively infrequent.

Peat Cutting ('Hiatus')

65.0 to 55.0cm is treated as a subzone of its own. During the analysis of tephra samples for the core, it became clear that only 10.0cm of sediment separated the Hekla 4 tephra (3,820 ^{14}C yrs BP) from the Glen Garry tephra (2,100 ^{14}C yrs BP). This might have reflected a slower accumulation rate or even sediment hiatus, but subsequent radiocarbon determinations for 63.0 cm (1971±39 ^{14}C years BP) and 60.0 cm (1964±39 ^{14}C years BP) reflected an apparent reversal in the chronological sequence.

Unfortunately, hiatuses cannot be reliably identified by changes in pollen data; abrupt changes which might be inferred as marking a hiatus could be caused by an alteration in sediment accumulation rates, sample size intervals or fluctuations in relative abundances of pollen types (Brown, 1988). There is a possibility that sediment is intact to 58.0cm, after which there is a rise in Cyperaceae and a few grains of *Callatriche stagnalis* were recorded. Sedges have been observed as an early coloniser of peat cuttings, (Giller & Wheeler, 1986; Rodwell, *et al.*, 1991b), *Callatriche stagnalis* is characteristic of muddy ditches, *Potamogeton* and *Nuphar* are also aquatic taxa characteristic of still water. However, these changes in these vegetation types could just as easily be related to vegetation communities elsewhere in the catchment. There are no records of other aquatics which Giller and Wheeler (1986) observed colonising abandoned cuttings, such as *Myriophyllum.*

A similar reversal of dates occurred in a mire in the Dod, Borders region with peat cutting as the inferred cause (Innes & Shennan, 1991). They suggested that the infilling of the trench with water caused decreased pollen concentrations by dilution of the peat. Percentage transmission values do not change significantly between 65.0 and 55.0 cm, which might reflect the deposition of vegetation in a water-filled peat cutting.

However, pollen concentrations do fall sharply at 63.0 cm, reversing a rising trend that began at 65.0 cm. Other evidence indicates an abrupt decline in the organic content to 15% between 62.0 and 60.0 cm. This could reflect the temporary drying out and mineralisation of the soil surface after cutting (*cf.* Rodwell, *et al.*, 1991b). However, percentage transmission values do not show changes which might indicate this.

Charman *et al.* (1995) suggested that peat cutting may have affected the mire at the site although they placed the possible location of the cutting much higher, near 10.0 cm. However, the chronology of the core from 50.0 cm seems to refute that observation. The constraints provided by the two tephra horizons and the reversal of dates between them in the core make it less likely that that a change in sedimentation rate is a causal factor. It is suggested that a hiatus in sedimentation, possibly caused by peat cutting, resulted in the apparent compression of the sequence between the two tephra horizons. The reversal in chronology indicated by the two radiocarbon determinations from 63.0 and 60.0 cm may have resulted from the introduction of more recent carbon into the sediments by root penetration as the cutting was re-colonised by vegetation (*cf.* Innes & Shennan, 1991).

Changes in pollen and peat stratigraphy cannot, therefore, be reliably related to the sequence before the Hekla 4 horizon or after the Glen Garry horizon. Nor can these changes be related to the archaeological data or the sequences from the other two sites in this study. The vegetation changes after 65.0cm indicate further reductions in woodland. Percentages of tree pollen fall below 20%, also indicating that the woodland became very open. Wet *Alnus* woodland and *Pinus* are the most adversely affected. By 59.0 cm, *Alnus* pollen is rare and both *Salix* and *Equisetum* pollen have disappeared. *Pinus* pollen percentages and concentrations also decline gradually, becoming rare by 59.0 cm. *Betula* percentages, which declined at 65.0cm, are largely unchanged between 64.0 cm and 55.0 cm, but concentrations are in a sustained decline until 58.0cm, indicating that some further areas of *Betula* woodland may have been lost, too. *Polypodium vulgare* which is epiphytic on *Betula*, is absent when *Betula* concentrations are at their lowest.

From 62.0 cm, *Corylus/Myrica* percentages and concentrations increase markedly. The better representation of *Corylus* may be related to increased flowering in a disturbed

woodland. *Calluna* percentages rise accompanied by more modest increases in pollen concentrations. *Calluna* may have colonised areas formerly occupied by *Betula* and *Pinus*. The presence of woodland herbs *Anemone nemarosa*, *Vicia*-type, *Silene dioica*-type and *Teucrium scorodonia* in the record may have been facilitated by disturbance in the woodland. The more open aspect of the local woodland is also indicated by the better representation of ferns after 65.0 cm, which also would have been transported more easily through the open woodland (*cf.* Moore, 1988).

Human activity is well represented between 64.0 and 58.0 cm. Microscopic charcoal fragments are frequently recorded and the predominance of large size classes indicates a nearby source. Poaceae percentages cease to expand after 62.0 cm, but grassland taxa such as *Plantago lanceolata, Rumex, Gentianella*-type, *Anthemis*-type, *Botrychium lunaria*, *Thalictrum*, *Urtica, Trifolium*-type, *Scabiosa,* and *Succisa pratense* are well represented. Arable activities continue to be recorded, although cereal-type pollen is only recorded on two occasions, herbaceous taxa associated with cultivation continue to be recorded frequently, and also include the moss *Cryptogramma crispa*, found on broken or bare ground.

A period of declining human activity near the site may be reflected from 58.0 cm, with proportions of microscopic charcoal decreasing. This is followed by increases in the pollen percentages and concentrations of most tree taxa. *Corylus* pollen percentages also decline slightly, but concentrations remain high, perhaps shaded out slightly by the more aggressive *Betula*. Both *Calluna* percentages and concentrations decline with the reductions of microscopic charcoal. If burning was involved with the expansion of *Calluna*, the cessation of relaxation of its management may have allowed *Betula* in invade areas of heath (*cf.* Gimingham, 1984; Legg, 1995), but the absence of grazing in any case would have permitted *Betula* seedlings to become established. Percentages of *Pinus* (15-20%) indicate that it may have been growing locally (*cf.* Bennett, 1984; Fossitt, 1994b). Arable indicators decline from 58.0 cm. Some grazing indicators, such as *Plantago lanceolata*, *Urtica* and *Trifolium*-type continue to be well represented, but others such as *Rumex* are less frequent. The catchment may not have been completely abandoned, besides indications that grazing was maintained, microscopic charcoal fragments are recorded more frequently from 57.0 cm.

Percentage transmission values change little during the 'hiatus', as already mentioned, indicating little significant change in mire hydrology. However persistent wet conditions may be inferred from the vegetation types recorded in the pollen record. *Lycopodium* is recorded when *Calluna* is better represented and is typically found on wet heaths. In general, taxa characteristic of wet, acid situations are frequent between 34.0 and 55.0cm. These include *Potamogeton*, which may have been growing in pools on the mire surface. *Drosera* is consistently recorded, and *Narthecium ossifragium* pollen makes its first appearance. *Sphagnum* percentages are consistently 2-5%. Cyperaceae pollen percentages are low and erratic, but in general this taxon is better represented with the decline in proportions of microscopic charcoal from 58.0cm.

KLD-1b
55.0cm-50.0cm
Betula-Corylus/Myrica-Calluna
ca. 2,160-1,940 to 1,890-1,690 cal BP
ca. 210cal BC- cal AD 10 to cal AD 60-260

Re-establishment of Woodland

The Glenn Garry tephra at 55.0 cm marks the end of the hiatus and the uncertainty concerning the continuity of the record. Between 55.0 cm and 50.0 cm the pollen record reflects the re-establishment of woodland in the catchment. There is an almost complete recovery of tree pollen percentages to pre-Hekla 4 values by 50.0 cm, as they reach 65%. *Alnus* percentages continue to rise and peak at around 10%, indicating a local presence (*cf.* Huntley & Birks, 1983). The re-establishment of *Alnus* woodland is accompanies by renewed records of *Salix* and *Equsetum*. Pollen percentages of *Betula* remain unchanged, but pollen concentrationsreturn to substantially higher values. Pollen percentages and concentrations of *Corylus* do not alter significantly. *Pinus* percentages reach 15%. Fossitt (1994b) suggested that values as low as 5-10% could indicate nearby growth of *Pinus* in stressed situations.

The mire surface was dominated by *Calluna*-rich vegetation. Percentages of *Sphagnum* and Cyperaceae are low, but Cyperaceae percentages recover after 52.0 cm. Herbs associated with wet, acid environments Ranunculaceae, *Drosera*, *Lycopodium* and *Potentilla* continue to be recorded and are joined by *Valeriana*. Percentage transmission values do not change significantly between 55.0 and 50.0 cm. Pollen

preservation is good, with a slight increase in corroded grains towards 50.0 cm.. Pollen concentrations indicate a generally increasing trend towards 50.0 cm.

The recovery of woodland was not permanent. From 53.0 cm, just before the zone boundary, there are indications of renewed woodland decline. After 53.0 cm, absolute and relative pollen frequencies of *Pinus* are in decline. Disturbances affecting the pine component of the woodland may account for the better representation of ferns from 53.0 cm. The disappearance of *Polypodium vulgare* spores coincides with reductions in *Betula* pollen. The reductions in tree pollen are accompanied by an increase in pollen percentages and concentrations of *Calluna* and a more modest rise in the abundance of Poaceae pollen. Pollen percentages and concentrations of *Alnus* are reduced from 52.0 cm, followed by similar reductions in *Betula* at 51.0 cm. On or near the mire, *Betula* may have been replaced by *Calluna*, as percentages and concentrations of the taxon increased modestly. On more fertile soils, *Betula* may have been replaced by *Corylus*, as there are also increases in the pollen percentages and concentrations of this shrub. These disturbances, affecting all three tree taxa, are likely to reflect anthropogenic pressures on woodland.

Between 55.0 and 51.0 cm, the period of highest tree pollen percentages and concentrations, indicators of human activity are very infrequent, but continue to be recorded. There is, however, a gap between 54.0 and 52.0 cm in grazing indicators such as *Plantago lanceolata, Plantago media/major, Rumex, Trifolium*-type and *Urtica.* There are also gaps in the record of pollen of arable herbs including *Artemesia*, Asteraceae, Chenopodicaeae and Caryophyllaceae. Microscopic charcoal is less frequent after 54.0 cm with fragments mostly divided between 20-30 μm and 60-70 μm. Evidence for declining woodland after 52.0 cm does not therefore appear to be associated with evidence for renewed burning. At 51.0 and 50.0 cm, cereal-type pollen is once again recorded, and from 52.0 cm, other herbaceous taxa associated with agricultural activity are more frequently recorded.

The sequence from Kildonan Lodge reflects a compression of chronology between the Glen Garry tephra at 55.0 cm and the next age estimation at 50.0 cm similar to that discussed for Loch Ascaig (Chapter 6). The sediment accumulation rate between 55.0 and 50.0 cm appears to at least 4 times slower than anytime after 50.0 cm. Due to the

hiatus, it is difficult to assess the potential significance of a change in accumulation rate, or whether as suggested for Loch Ascaig, the dating of the Glen Garry tephra remains too imprecise.

LPAZ KLD-2a
50.0cm-42.0cm
Betula-Calluna
1,700-1,510 to 1,530-1,330cal BP
AD 260-420 to 420-620 AD

Continued Woodland Decline and a 'Dark Age' Climatic Deterioration

Pollen percentages and concentrations of *Alnus* are further reduced across the zone boundary at 50.0cm and values indicate that it was reduced to a sparse presence (*cf.* Huntly & Birks, 1983). *Betula* appears to be the only component of the woodland not affected by clearance or other disturbance processes. *Betula* pollen percentages are initially unchanged, but pollen concentrations rise from 50.0cm. The general openness of the woodland, however, is indicated by the good representation of ferns (*cf.* Moore, 1988), although the frequency and variety of woodland herbs has declined to occasional grains of *Anemone nemorosa*. *Corylus* percentages show an initial and substantial increase pollen concentrations before declining abruptly. Pollen of *Pinus* declines to a rare presence in the profile after 50.0 cm. The frequency of ferns continues to increase, except for the epiphytic *Polypodium vulgare*. Poaceae percentages and concentrations increase modestly, and briefly after 50.0 cm. *Calluna* pollen percentages and concentrations reflect rising values until 50.0cm.

Proportions of microscopic charcoal are higher between 50.0 and 47.0 cm, and over half are >70μm. Cereal-type pollen is recorded until 49.0 cm, and arable indicators *Artemesia*, Asteraceae and Caryophyllaceae are increasingly rare. Grazing and other open ground indicators, such *Botrychium lunaria*, *Rumex*, *Thalictrum* continue to be recorded, while *Urtica* and *Plantago lanceolata* grains are more frequent. The re-appearance of *Pteridium* indicates that the amount of open ground was increased possibly due to burning as indicated by the rise in microscopic charcoal.

Percentage transmission values begin a persistent rising trend from 47.0 cm. Cyperaceae percentages rise and peak at 48.0 cm before showing signs of decline before

the top of the KLD 2a subzone boundary. *Sphagnum* values do not change significantly. Mire vegetation communities containing *Thelypteris palustris*, *Drosera*, *Potentilla*-type and Ranunculaceae continue to be well represented. Declines in total pollen concentrations mirror the rise in percentage transmission values. Pollen preservation is generally good.

Re-establishment of *Betula* Woodland and Possible Abandonment of Settlement

From 48.0 cm, pollen percentages and concentrations of *Betula* rise. At 44.0 cm (AD 415-640/1550-1340 cal BP), *Betula* woodland recovers the dominant status not seen since KLD-1, as values rise to 40%. A modest rise in *Alnus* percentages and concentrations indicate that woodland in wetter areas was also re-established. *Corylus/Myrica* pollen percentages and concentrations are reduced. The proportions of ferns are reduced, and although renewed records of *Polypodium vulgare* accompany the initial rise in abundance of *Betula* pollen by 46.0 cm it as absent, as increasing forest cover limited its dispersal capacity.

Pollen percentages of *Calluna* remain virtually unchanged between 50.0 and 42.0 cm. However, with the rise in percentages and concentrations of *Betula* from 46.0 cm, concentrations of *Calluna* are reduced, indicating that some areas of heathland may have been colonised by *Betula*. This may be related to the reduction in microscopic charcoal at 48.0 cm, indicating both a reduction in grazing, which would have permitted *Betula* regeneration, as well as a cessation in potential heathland management, reducing the competitive vigour of heather (*cf.* Gimingham, 1984; Legg, 1985).

Renewed Agricultural Activity

Renewed human activity may be responsible for the decline in *Betula* after 44.0 cm. This is accompanied by reductions in the relative and absolute pollen frequencies of other woodland taxa which are characteristic of different environments such as *Alnus* and *Corylus*. There is a brief but substantial reduction in *Corylus*, as well, at 41.0cm, which may indicate that part of the *Betula-Corylus* woodland was removed. Microscopic charcoal is still recorded infrequently, although there is a modest peak at 42.0 cm. Fragments are derived mainly from the smaller size classes. There are also increases in Poaceae percentages after 42.0 cm. There may have been some increases in the amount of grassland; *Polygala vulgaris*, commonly associated with 'ancient'

grassland (Grime *et al.*, 1990), is recorded and other open ground indicators associated with grazing activity or grassland are better represented such *Plantago lanceolata*, *Botrychium lunaria* and *Disphasiastrum* and as other taxa characteristic of disturbed habitats such *Plantago media/major* and *Rumex*. Arable activity continues to be poorly represented.

The 'expansion' of woodland and interpretation of abandonment should be approached cautiously (Edwards, 1983; Edwards & Whittington, 1998; Tipping, 1994), but the infrequent records of microscopic charcoal, with the regeneration of woodland strongly support a lack of human interference, at least nearby. Even if woodland filtered out the anthropogenic pollen signal (Edwards, 1979, 1981) and larger fragments of charcoal, a high degree of burning activity near to the site should still be represented by frequent records of smaller particles, which does not appear to be the case after 47.0cm. However, the presence of taxa such as *Polygala vulgaris* and even the infrequent records of grassland herbs indicate that areas of grassland were maintained. Even if the focus of settlement was moved elsewhere in the catchment, areas around the mire may have been continued to be used for grazing.

Lpaz KLD-2b
42.0-31.0cm
Betula-Corylus
ca. 1,530-1,330 to 1,130-980 cal BP
ca. cal AD 420-620 to 820-970

Woodland, Erosion and Agricultural Activity

The reductions in tree pollen which began in the previous zone continue until 38.0cm. *Betula* percentages indicate it was still locally important (*cf.* Huntly & Birks, 1983), and at 38.0cm recovers for a second time, although percentages are slightly lower than those seen in KLD-2a. *Alnus* shows some signs of recovery, but pollen percentages and concentrations do not regain earlier values The substantial rise in *Corylus/Myrica* pollen is the most notable change. *Corylus/Myrica* percentages reach the highest yet recorded, maintaining values of 30% or more. Pollen concentrations of this taxon also increase. Poaceae percentages and concentrations continue to be low. *Calluna* percentages decrease after 42.0 cm, but pollen concentrations do not change significantly between 42.0 and 31.0 cm. Proportions of microscopic charcoal initially

maintain the lower values seen at the end of KLD 2a, before becoming increasingly frequent from 35.0 cm.

Mire Communities and Palaeohydrology

Percentage transmission values continue their increasing trend before peaking at 32.0 cm. The inferred wetter conditions are accompanied by higher, although slightly erratic, *Sphagnum* percentages. Cyperaceae percentages are generally reduced, and it is rarely recorded between 38.0 and 31.0cm. Despite the evidence for increasingly wet conditions, taxa such as *Drosera*, *Potentilla*-type, *Viola palustris* and Ranunculaceae are generally less frequently recorded, although *Thelypteris palustris* is recorded at 34.0cm. Species diversity may have declined as conditions under persistently wet, acid mire surface conditions, promoting the dominance of *Sphagnum* species (Keatinge *et al.*, 1995). Poor pollen preservation, especially the high proportion of corroded and degraded grains, may be reworked pollen from the mineral soils eroding into the catchment; higher pollen concentrations may also be related to the influx of reworked pollen grains. Both are the opposite of what might be expected during a shift to wetter conditions. From 32.0cm, percentage transmission values enter a steep decline.

Expansion of *Corylus/Myrica*-type and possible Woodland Management

Proportions of *Corylus/Myrica* reach their highest recorded during KLD 2b. The evidence for increasingly wet acid conditions on the mire surface may indicate that *Myrica gale* was contributing to the pollen rain. However, given the poor pollen production of this taxon (*cf.* Huntly & Birks, 1983), it is unlikely to account for the dramatic rises in both pollen percentages and concentrations between 42.0 and 31.0 cm. Except for the brief period of woodland recovery between 37.0 and 34.0 cm, *Corylus* appears to consistently dominate the woodland, apparently at the expense of *Betula*, for the first time. One possible explanation is that *Corylus* was preferentially managed by coppicing, which in short intervals, will increase its pollen productivity (*cf.* Rackham, 1980, 1988). Management by coppicing can only be tentatively suggested because of the low resolution of the record which blurs any distinctive changes in abundance associated with coppicing and harvesting, and the difficulty in taxonomic distinction between *Corylus avellana* pollen and *Myrica gale*.

Erosion

A notable feature of KLD 2b is the substantial reduction of the organic content of the sediment from 40.0 cm and continuing throughout the subzone. This is accompanied by a substantial rise in corroded, and to a lesser extent, crumpled grains. The decline in pollen preservation probably indicates the addition of reworked pollen into the sediments, carried down slope with minerogenic material. The removal of woodland at the beginning of KLD 2b, exposing mineral soils to increased surface run-off, could be implicated, but evidence for mineral inwashing continues after indications that woodland was regenerating after 38.0 cm

The evidence for mineral inwashing could be linked to both the evidence for increased effective precipitation and possible human activity on the slopes above Kildonan Lodge; delineating the influence of the two processes in a single peat core cannot be done with any certainty (*cf.* Ballantyne, 1991). However, some inferences can be made, but more reliable interpretations could be formulated with further studies of Holocene geomorphological activity in the catchment. Arable activity is not strongly represented in the profile between 42.0 and 31.0 cm. There are a few sporadic occurrences of herbs associated with arable activity such as *Artemesia*, Asteraceae and *Fumaria*, and a single grain of cereal-type pollen was recorded at 31.0 cm. In general, pastoral activities are more consistently represented pollen of *Plantago lanceolata*, *Rumex*, *Urtica*, *Trifolium*-type and occasional *Polygala vulgaris*.

The regeneration of woodland apparent between 37.0 and 34.0 cm may not indicate the complete abandonment of the catchment, merely the regeneration of woodland around the mire (*cf.* Edwards, 1981; Whittington & Edwards, 1998). The continued inwash of mineral matter indicates that mineral soils above the site continued to be disturbed. Vuorela (1985) suggested that the mineral content of peat sediments was a good indicator of arable activity, although the evidence for cultivation is equivocal for most of the subzone. Edwards *et al.* (1991) noted a close correlation between minerogenic deposits in peat and palaeoecological evidence for vegetation disturbance and human activity at a site in southern Scotland. Although the exact nature of the activities at their site was unclear, it was proposed that grazing animals on hill slopes may have exposed sub-peat mineral soils. At Upper Suisgill, Barclay (1985) surmised that 'gullying'

caused by movement of livestock across the hill slopes above the settlement may have contributed to the episodes of considerable erosion recorded.

Light grazing pressure may not necessarily be accompanied by erosion (Bunting, 1996), but heavy grazing pressure, particularly in areas of wetter soils will pose a problem. Trampling of soils in upland areas leaves them susceptible to increased run-off, erosion, sediment yield and decreased infiltration (Butler, 1995). Trampling by animals is significant as a geomorphic process particularly when animals are moving up slopes and over hills because when walking, most of their weight is placed on a single hoof, producing large vertical and shearing stresses in the soil (Trimble & Mendel, 1995). Soil 'poaching' is recognised as a serious problem even in modern agricultural systems (Ellis & Mellor 1995; Greenwood *et al.*, 1998). Regular poaching of the soils will cause a compact layer to form 7-12cm below the surface (Batey, 1988) and together with removal of vegetation cover by stock, and burning, increases the exposure of soils, accelerates erosion and loss of nutrients through leaching (Ellis & Mellor, 1995). Animals are creatures of habit, and can create trails as deep as 30 cm in places, especially in wet soils which can act to channel run-off (Trimble & Mendel, 1995). Animals used for traction can also alter soil status; the use of draft animals for pulling mould board ploughs was recognised as a serious source of soil compaction and impeded drainage in the 19th century (Soane & van Ouerwerker, 1992).

KLD-3a
31.0-16.0cm
Betula-Corylus/Myrica-Poaceae
ca. 1170-970 to 730-620 cal BP
cal AD 720-970 to 1220-1330

Replacement of heath by grassland.

Organic content of the sediment continues to be reduced, although it begins to increase towards the subzone boundary at 18.0 cm. The absence of pollen counts between 23.0 and 20.0 cm is due to the presence of a very large wood macrofossil. The most notable change in KLD 3a is the substantial reduction in the relative and absolute abundance of *Calluna* pollen. It appears that *Calluna* heath may have been replaced by grassland, because the primary response to the reductions in this taxon, are increase in the relative and absolute frequencies of grass pollen. Poaceae percentages reach the highest

recorded, 20-25% between 31.0 and 16.0 cm. Microscopic charcoal is frequently recorded, 50-60% of the fragments derive from the larger size classes, but a significant proportion, 30-40%, measure 20-30μm. Wet *Alnus* woodland may have become an increasingly sparse component of the vegetation in the catchment. Values are generally under 2% and pollen concentrations of this taxon are very low. Relative and absolute pollen abundances *Betula* and *Corylus/Myrica* type indicate they were still locally important components of the vegetation. However, from 31.0 cm *Corylus/Myrica* percentage gradually, but modestly, decline. Reductions in *Betula* pollen percentages are similarly modest. From 20.0cm, pollen concentrations of both these types are abruptly reduced.

Percentages of *Pteridium* rise substantially, indicating that the amount of open ground was increased, but may also attest to the importance of fire in vegetation change, being one of the few pyrophitic plants native to Britain (Edwards & Whittington, 2001). The presence of *Selaginella selaginoides*, along with the increased representation of Cyperceae, consistently high values for *Sphagnum* and rise in Poaceae indicates that nutrient poor, damp sedge grasslands were a characteristic vegetation type around Kildonan Lodge (*cf.* Edwards & Whittington, 1998b). However, other pollen types such as *Galium, Heracleum sphondylium, Polygala vulgaris, Urtica, Thalictrum, Trifolium*-type, *Succisa pratense, Plantago lanceolata* and *Plantago media/major*, particularly frequent towards the top of the zone, are characteristic of more productive grassland (Greig, 1988; Rodwell *et al.*, 1991c). Pollen types associated with arable activity occur sporadically, including individual grains of cereal-type pollen at 25.0 and 16.0 cm. Herbaceous taxa include *Artemesia*, *Fumaria*, Caryophyllaceae and Chenopodiaceae.

Percentage transmission values continue the declining trend which began at 32.0cm. The abundance of *Calluna* pollen is reduced. Despite the apparent shift to drier conditions, *Sphagnum* percentages are generally maintained or increased. *Sphagnum* percentages, except for a single spectra at 27.0cm, are increasing. Cyperaceae remains little changed with values fluctuating around 10%. From 18.0cm, percentage transmission values increase, accompanied by a sharp rise in *Sphagnum* percentages. Other mire vegetation are recorded more frequently including Ranunculaceae, *Potentilla*-type, *Viola palustris*, and *Thelypteris palustris*, as well as aquatics

Potamogeton and *Nuphar*. *Lycopodium* which prefers areas of wet heath is recorded between 19.0 and 16.0 cm. Pollen preservation continues to be poor, reflecting a high proportion of corroded grains. Total pollen concentrations also do not alter significantly.

The inference of heavy grazing made in relation to the onset of erosion in KLD 2b appears to supported by the vegetation changes in KLD 3a. Heavy burning and grazing may have resulted in the conversion of areas of heathland to grassland (Birse, 1980; Legg, 1985). Human activity, along with the increasing acidification of soils in the catchment may have created adverse conditions for *Alnus* which does not tolerate extremely acid conditions (*cf.* Savil, 1991). Activities still do not appear to have greatly impacted the *Betula* woodland. The reduction in *Corylus* pollen abundance, especially after 16.0 cm may indicate, that if it had been preferentially managed earlier, it was from 30.0 cm, becoming an increasingly less important component of the vegetation. This, too, may be related to increasing soil acidification, as suitable environments for *Corylus* declined. The increasing acidification of soils in the catchment was possibly influenced by increased precipitation, burning and grazing (*cf.* Moore, 1988). Another possibility is that areas of former coppice woodland were cleared to extend grazing., and *Corylus* was then confined to the broadleaved woodland with *Betula*.

From 20.0 cm, microscopic charcoal is recorded less frequently. *Pteridium* spores are less frequent with an inferred reduction of vegetation burning. There are gaps in the and frequency and variety of disturbance taxa, but grassland and grazing indicators are still present. *Rumex* percentages increase briefly to 2-5%. This may reflect fallowing or the abandonment of pasture. The conditions for the rise of *Rumex* at Kildonan appear to have been different at Loch Ascaig, where it was associated with some evidence for increased minerogenic input and more reliable indicators of arable activity (Chapter 7). As discussed in Chapter 7, the interpretation of *Rumex* curves can be complicated because it can be reflective of fallow, cultivated and grazed (heath) land (Behre, 1981).

Lpaz KLD-3b
16.0-0cm
Calluna-Betula/Corylus
ca. 725-620 cal BP to present
ca. cal AD 1225-1330 to present

Relative and absolute pollen frequencies of *Calluna* recover from 16.0cm. This has an immediate impact in the relative pollen frequencies of *Betula* and *Corylus/Myrica*, but pollen concentrations of these taxa show increases. Percentages of *Sphagnum* are substantially reduced. Cyperaceae is also better represented. Taxa characteristic of waterlogging and pooling, *eg. Potamogeton* and *Thelypteris palustris* continue to be recorded. Percentage transmission values indicate a modest rise from 16.0 cm, but this probably represents the boundary between active acrotelm and catotelm processes, rather than hydrological variations After 16.0cm, microscopic charcoal is less frequently recorded. Pollen of herbaceous taxa associated with arable activity are almost entirely absent after 16.0cm. Grazing and grassland indicators continue to occur sporadically, including *Plantago lanceolata, Plantago media/major, Rumex, Urtica, Botrychium lunaria, Disphasiastrum* and *Trifolium*-type. However, the decreasing diversity and frequency indicates the increasing dominance of *Calluna* heath in the catchment.

Summary of Kildonan Lodge

The interpretation of this core is hampered by the hiatus between 65.0 and 55.0cm. Firstly, this makes understanding long term Late Holocene vegetation dynamics difficult and prevents setting more recent change into a secure context. Secondly, and importantly for the purpose of this investigation, the entire later prehistoric sequence is missing. A summary of late Holocene climate changes is presented in Table 8.2. There are significant changes regarding land-use, vegetation change and climate during the Dark Age which are intriguing, especially in comparison with the evidence from Loch Ascaig (Chapter 7).

Depth (cm)	Type	Calibrated Radiocarbon Years BP	Calibrated Calendar Years BP
55.0cm	Wet	Just after *ca.* 2160-1940 (Glen Garry tephra)	*ca.* 210 cal BC-10 cal AD
47.0cm	Wet	*ca.* 1530-1335	*ca.* cal AD 415-640
34.0cm	Dry	Just prior to *ca.* 1260-1065	*ca.* cal AD 870-1020
18.0cm	Wet	*ca.* 725-620	*ca.* cal AD 1225-1330

Table 8.2. Summary of palaeohydrological shifts at KLD.

Kildonan Lodge is much smaller peat basin, recording more local vegetation than the blanket mires of Loch Ascaig and Kinbrace Hill. Both the pollen data and the frequent finds of wood macrofossils (mostly near the bottom of the profile) indicate that, unlike the other two sites in this study, woodland has been an important component of the vegetation from just before *ca.* 4,360-4,090 cal BP until fairly recently. This is confirmed to some extent by documents of the Sutherland Estate. The decline of woodland is documented in the diaries of William Young, factor for this part of the Sutherland estate in the early 19th century, but he indicates that remnants of woodland still existed around 'Craggy' Water. However, in a letter to the Marchioness of Sutherland, he warned that without strict measures, forest would soon succumb to the depredations of the tenantry (Adam, 1972).

There are no clear indicators as to the causes of woodland disturbance prior to *ca.* 4,360-4,090 cal BP. Human activity may have had some role to play. There is evidence for early occupation of the catchment in the form of a long cairn. It is impossible to ascertain, however, how the timing of the construction and use of the cairn may relate to the evidence for woodland disturbance and subsequent human activities in the Kildonan Lodge catchment. Long cairns such as these are generally ascribed to the period 3700-2500 BC (Adkins & Adkins, 1982), but some suspect the building of megalithic tombs may have continued longer in northern Scotland (Mercer, 1996). From *ca.* just prior to 4360-4090 cal BP (2410-2140 cal BC), human activity is more apparent, presumably as clearings were made, or were closer to the mire edge. The persistence of woodland around the mire probably contributed to a general under representation of agricultural activities throughout the profile. Percentage transmission values indicate relatively dry surface conditions, giving no indication that fluctuations in climate might be related to the disturbances in the woodland.

Little can be said about how the changes in vegetation between 65.0 and 55.0 cm relate to either later prehistory or the first millennium AD. The early part of the phase seems to reflect substantial woodland clearance in the catchment, and there are indications that both cultivation and grazing were important activities. From 58.0 cm, however, the re-establishment of woodland, decline in burning and decreased frequency of agricultural indicators points to a lessening of anthropogenic pressures, possibly culminating in the abandonment of the catchment, or at the very least the relocation of activities further

away from the basin. *Pinus* appears to have been re-established locally as human activity waned.

The continued presence of *Pinus* might indicate a continuity of the sequence from 57.0 cm, but this is only a tentative suggestion, and the reversal of radiocarbon dates between 65.0 and 55.0cm show there is little scope for resolving the issue. There are some indications of anthropogenic forest clearance, as pollen of *Pinus* and *Alnus*, which occupy different environments, are reduced. Again *Betula-Corylus* woodland appears to be relatively unaffected compared to other taxa. Cultivation is initially indicated by cereal-type pollen and arable herb taxa, but grazing appears to be the more important activity. The evidence for this activity coincides with indications of a shift to wetter climate conditions.

The modest fluctuation in percentage transmission values agrees with data from both Loch Ascaig and Kinbrace Hill which suggests a shift to conditions *ca.* 2160-1940 cal BP (210 cal Bc-cal AD 10), well constrained by the presence of the Glen Garry tephra horizon. Arable and pastoral activity continues to be recorded; it is not until 50.0cm or 1700-1510 cal BP (cal AD 255-420) that human activity begins to decline—at a time when the percentage transmission curve reflects a return to slightly lower values. Between *ca.* cal AD 255-420 and *ca.* cal AD 415-640 woodland undergoes a sustained recovery and human activity does not figure prominently in the record. After *ca.* cal AD 415-640, there is renewed clearance accompanied by agricultural activity despite evidence for the persistence of wetter conditions.

From *ca.* cal AD 560-670 heavy grazing and increased precipitation may caused the erosion of mineral sediments in the catchment. Despite the regeneration woodland of woodland, the continued erosion of mineral matter into the sediment is a strong indication that soils and/or vegetation of the continued to be disturbed, a situation possibly exacerbated by increased precipitation. From *ca.* cal AD 690-890, areas of *Betula* and *Alnus* woodland were cleared, but again clearance was not complete, and areas of woodland were either conserved, or the uptake of more extensive tracks of land was not necessary.

The inferred 'Dark Age' agricultural activities may overlap with the construction of a clearance cairn in the Craggie Water catchment, *ca.* cal AD 530-720 (*cf.* Russell-White, 1997). Grazing seems to be the most important activity from *ca.* cal AD 415-640 onwards, with little evidence for reductions in pressure. The clearance cairn and ard marks from near the Allt na h-Airbhe, the estimated to have been made prior to *ca.* cal AD 530-970 (*cf.* Russell-White, 1998), indicate that arable activities may have been focused primarily upslope, away from the sampling site. This may explain why they are largely undetected in the pollen diagram. Other than the evidence for cairn construction and cultivation from Allt na h-Airbhe, there is little archaeological evidence which can be confidently ascribed to the first millennium AD in the Strath (RCAHMS, 1993). It is also tentatively suggested that the predominance of *Corylus/Myrica* type between cal AD 415-640 until at least cal AD 870-1020 represents the management of *Corylus avellana* by coppicing.

From *ca.* cal AD 870-1020, after the inferred shift to drier conditions, pressures on the woodland increase, with the abundance of *Betula* and *Corylus/Myrica* affected. Heavy grazing and burning resulting in the conversion of heathland to poor grassland persists until *ca.* AD 1225-1330. It is not clear why, but it appears a more favourable management regime, or perhaps a decline pressure relating to the human or livestock population of the catchment, allowed *Calluna* to establish its dominance. The period of inferred drier mire surface conditions between *ca.* cal AD 870-1020 and *ca.* cal AD 1225-1330 coincides roughly with other evidence for climatic amelioration at this time, *ie.*, the Medieval Warm Period (Chapter 2). The expansion of *Calluna* from *ca.* cal AD 1225-1330 is roughly contemporary with a similar expansion of heathland at Kilearnan Hill (*cf.* Birnie, *unpub*), just 5km to the east of Kildonan Lodge.

Settlements of the first millennium AD and after are not known with any certainty. The township of Duible, may date from the medieval period or after, although the place name itself seems to have originated in the Norse period. There is also a 'homestead' located near the Allt na h-airbhe, but this, too, is of unknown date, but it has been suggested that structures such as this might fill the first millennium AD settlement lacuna apparent from survey (RCAHMS, 1993). These episodes of later first millennium activity recorded in the Kildonan Lodge profile could represent the indigenous 'Pictish' population, as well as overlap with Gaelic migrations into the

uplands after the 8th and 9th centuries AD. The name Kildonan, 'cell of Donan', relates to the presence of early Christianity in the Strath, as do other place names with the 'Kil' element, but there are no formal historical references to Christianity in Sutherland until the 12th century. The archaeology and settlement of the first millennium AD is poorly understood across the north in general. All that can be said with any certainty is that these names date from sometime after Columba's mission began in AD 563 and prior to the 12th century AD Place name evidence for Viking settlement is apparent around Kildonan Lodge in names such as Duible, Oulmsdale, and of course, Helmsdale, but it is impossible to relate these historic 'events' to the palaeoecological record, especially without any corroborating archaeological evidence. The changes from the 18th century, marked by the Katla tephra at 14.0cm, indicate the continued importance of heathland and woodland both in the catchment to the present day.

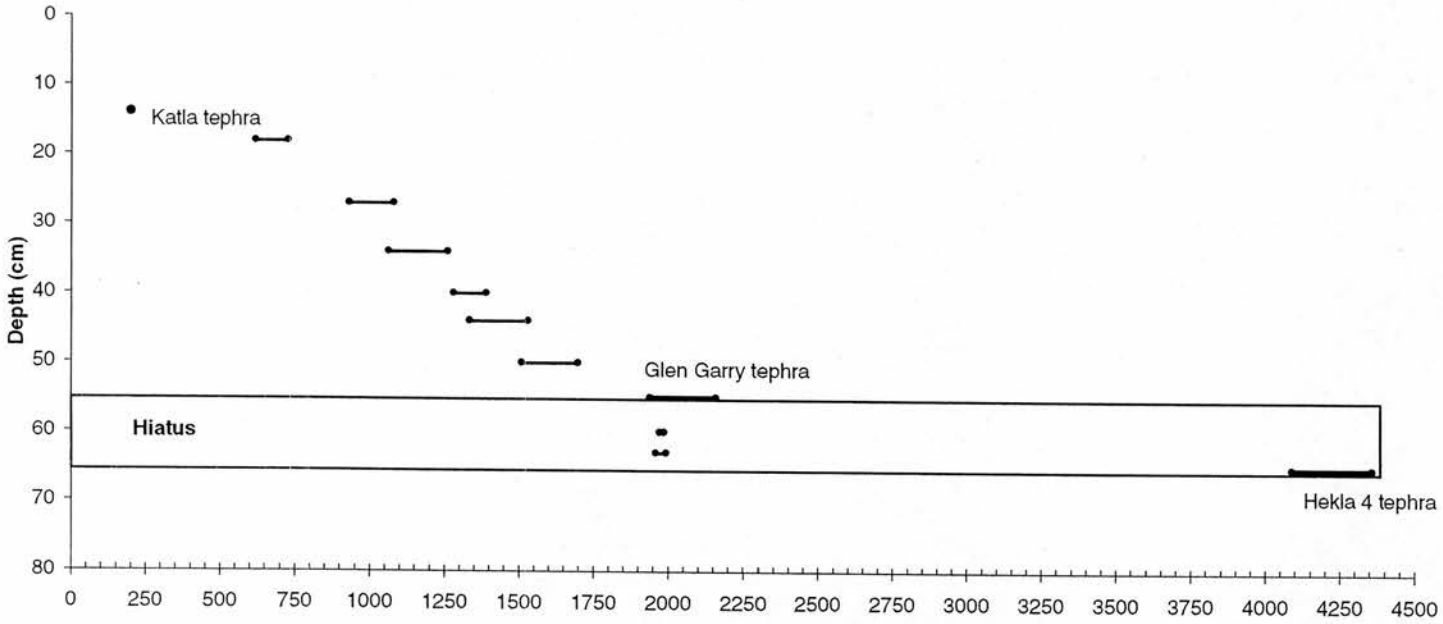


Figure 8.1. Kildonan Lodge. Calibrated Calendar Years BP with tephra horizons.

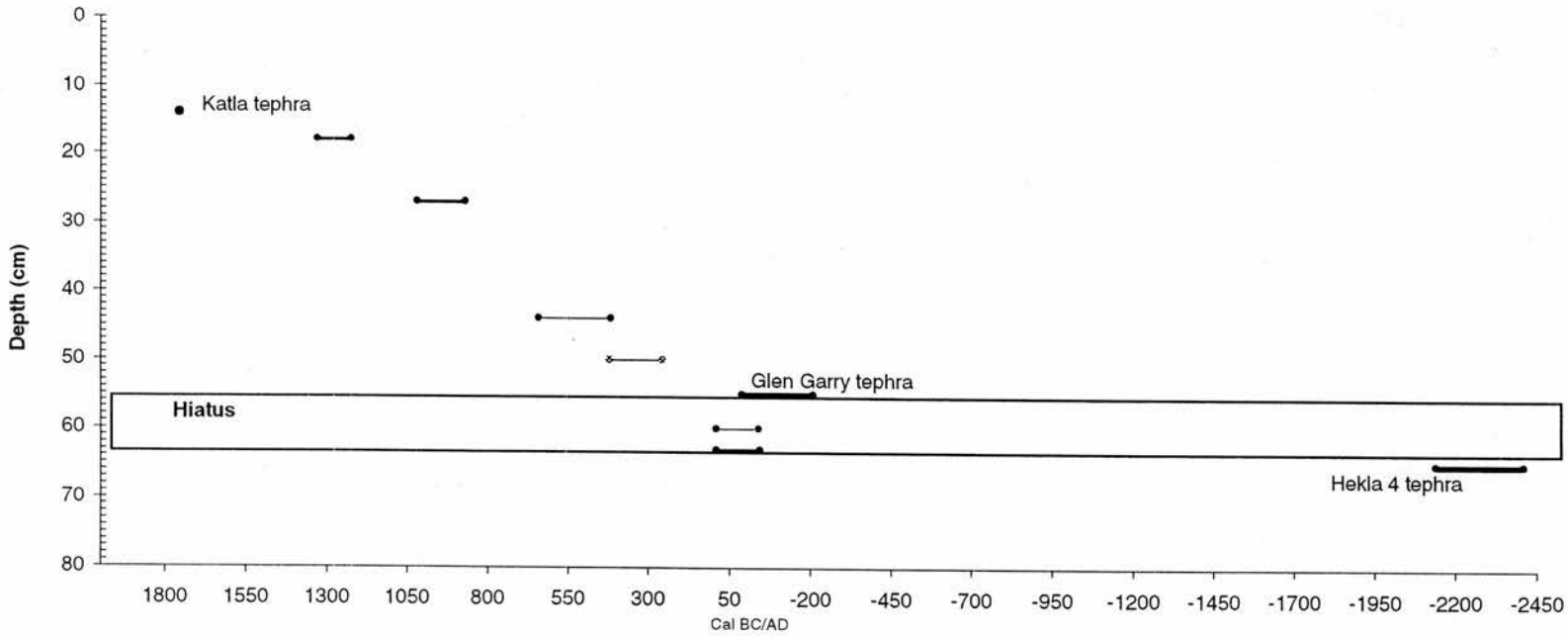
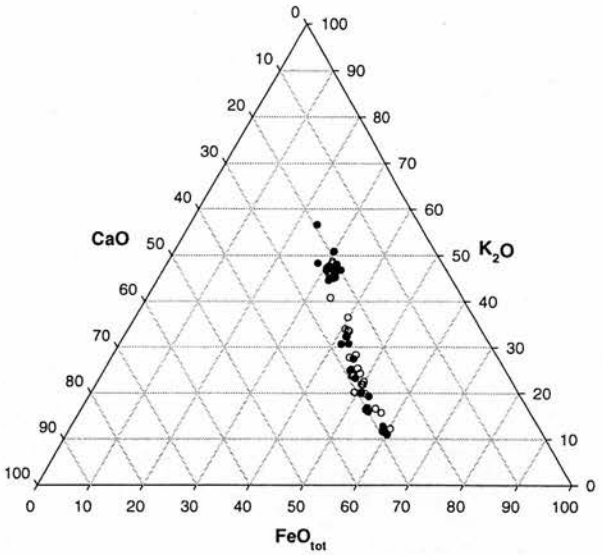


Figure 8.2 Kildonan Lodge. Calibrated calendar years BC/AD with tephra horizons.



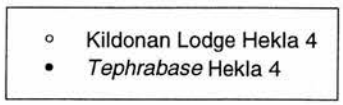
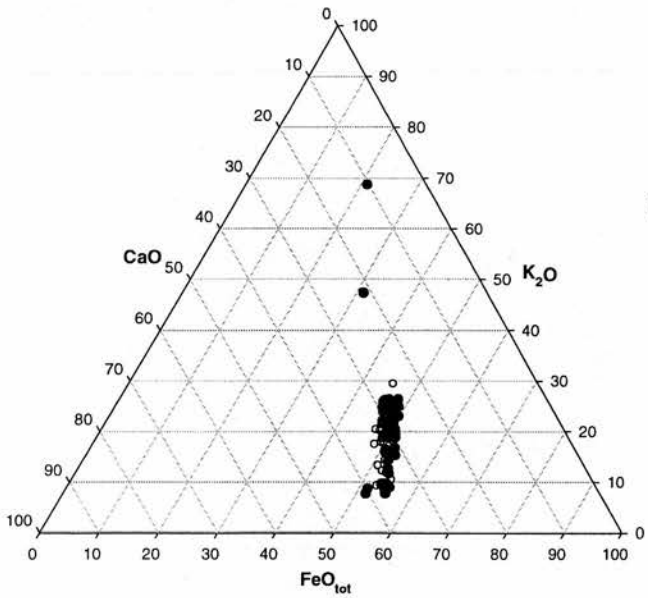


Figure 8.3. Kildonan Lodge. Hekla 4 tephra.



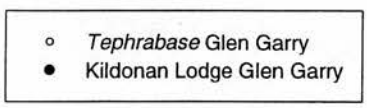
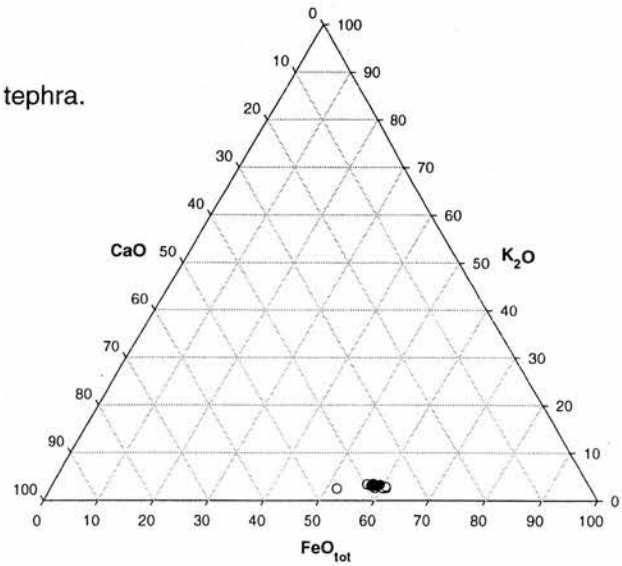


Figure 8.4. Kildonan Lodge. Glen Garry tephra.



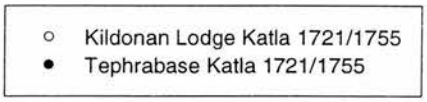


Figure 8.5. Kildonan Lodge. Katla 1721/1755 tephra.

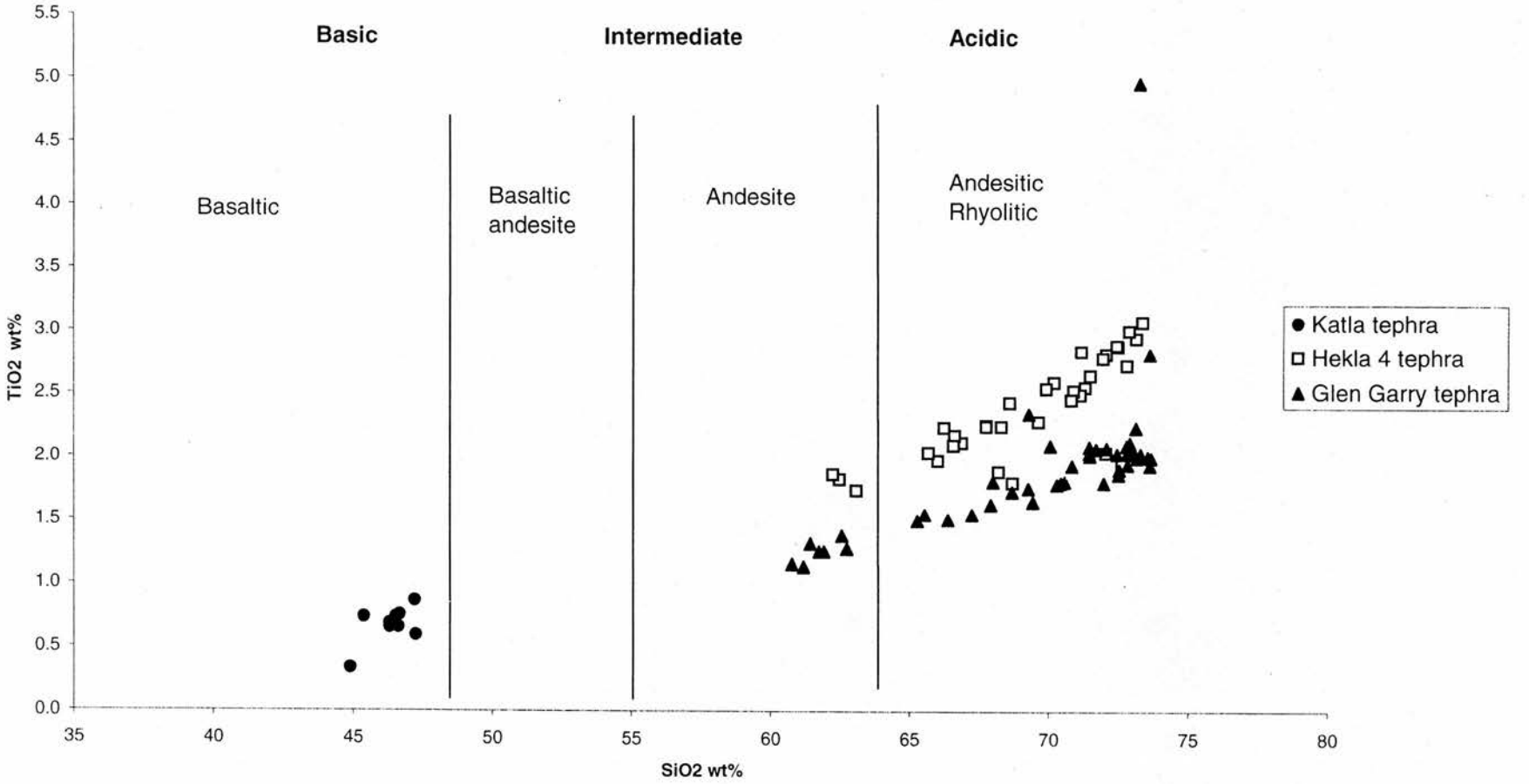


Figure 8.6. Discrimination of the basaltic Katla tephra and silicic Hekla 4 and Glen Garry tephras. Discriminations are based on potassium and silica content (after Dugmore et al., 1995).

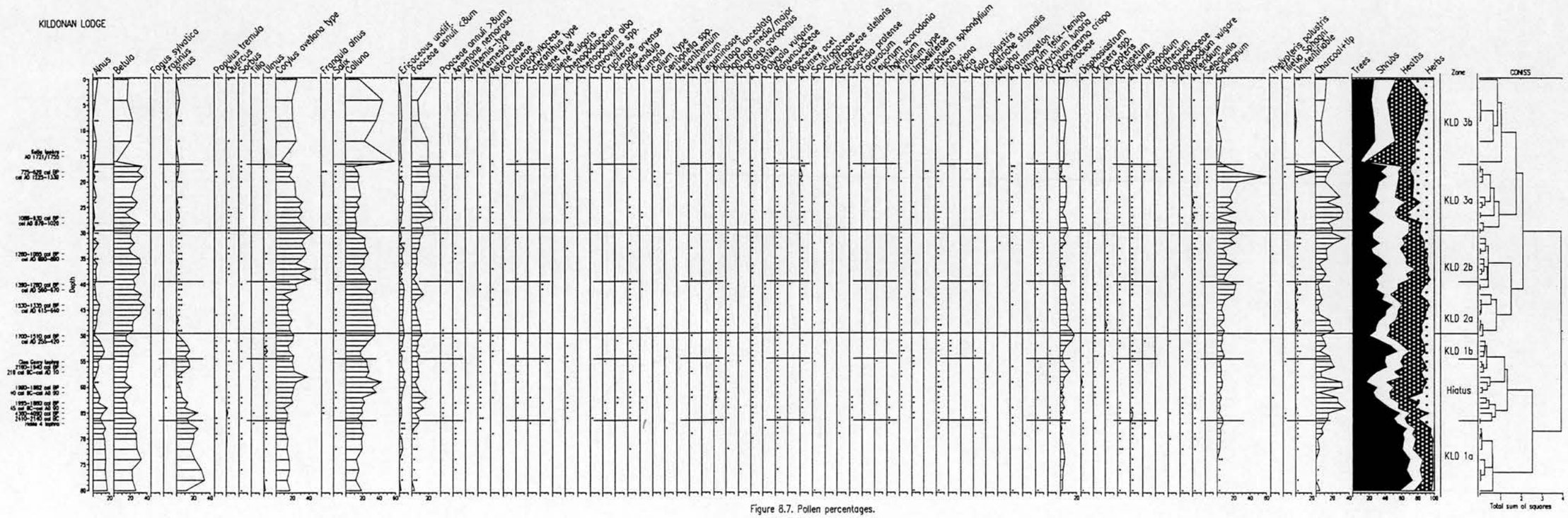


Figure 8.7. Pollen percentages.

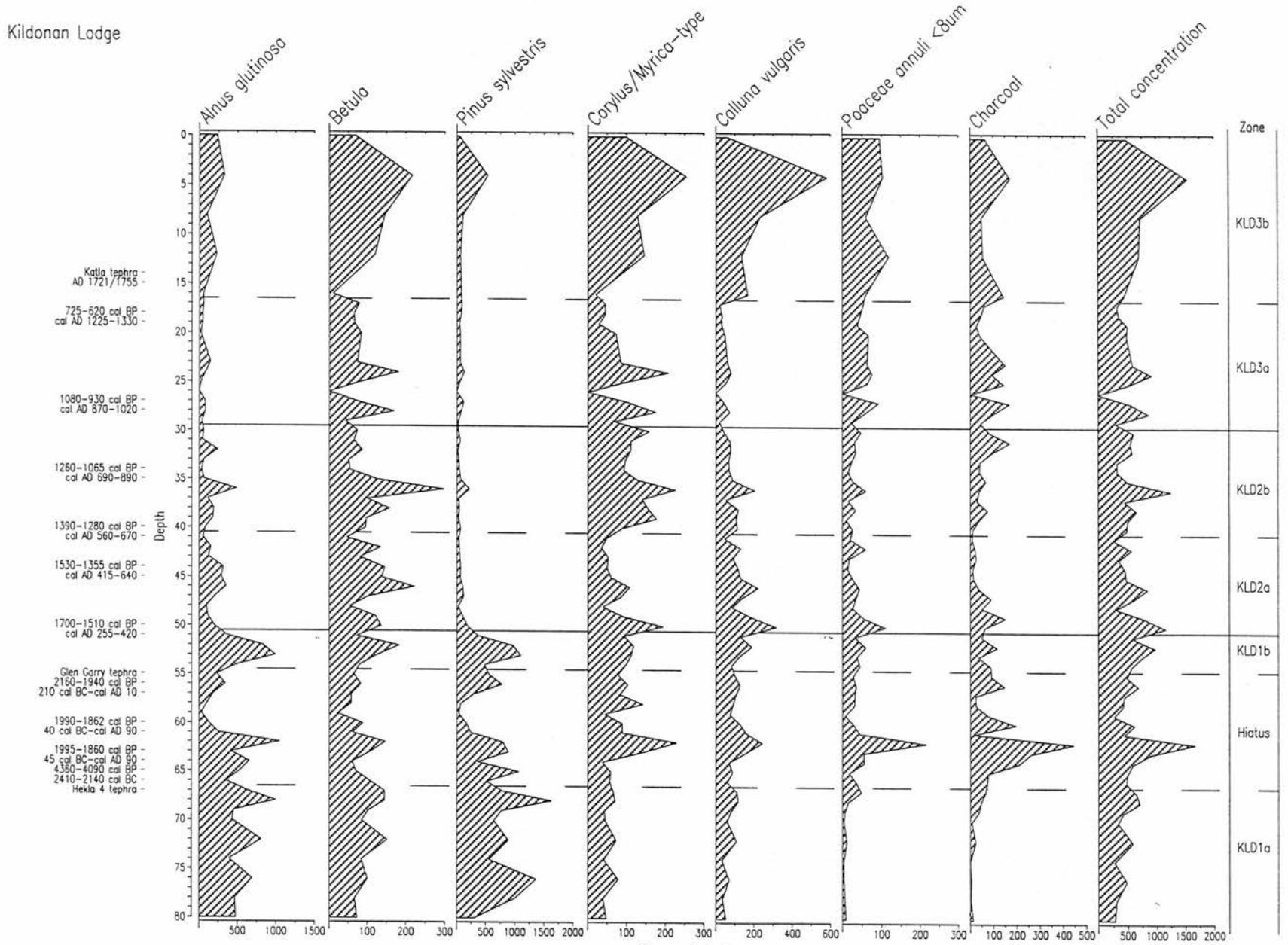


Figure 8.8. Pollen concentrations.

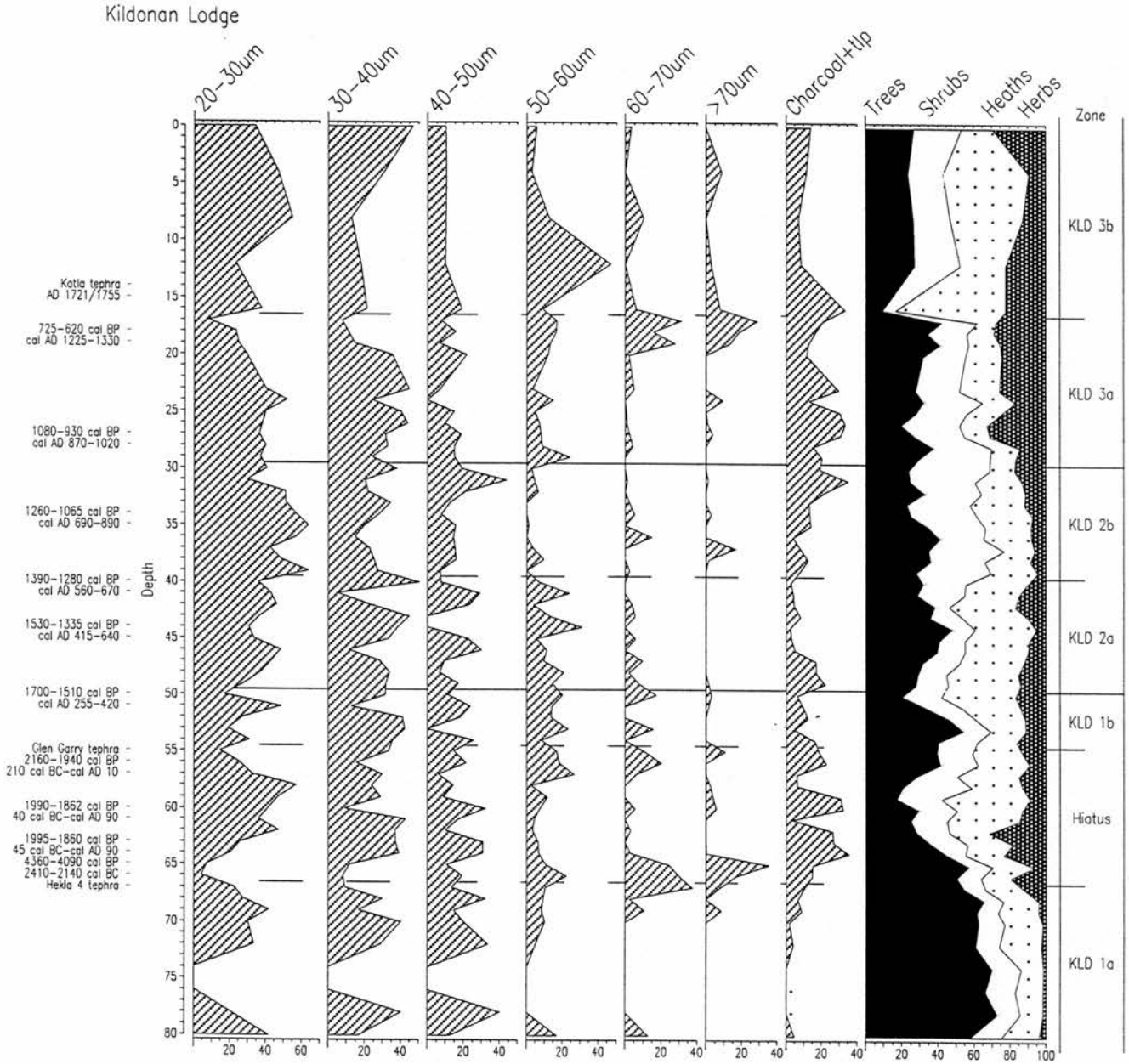


Figure 8.9. Microscopic charcoal.

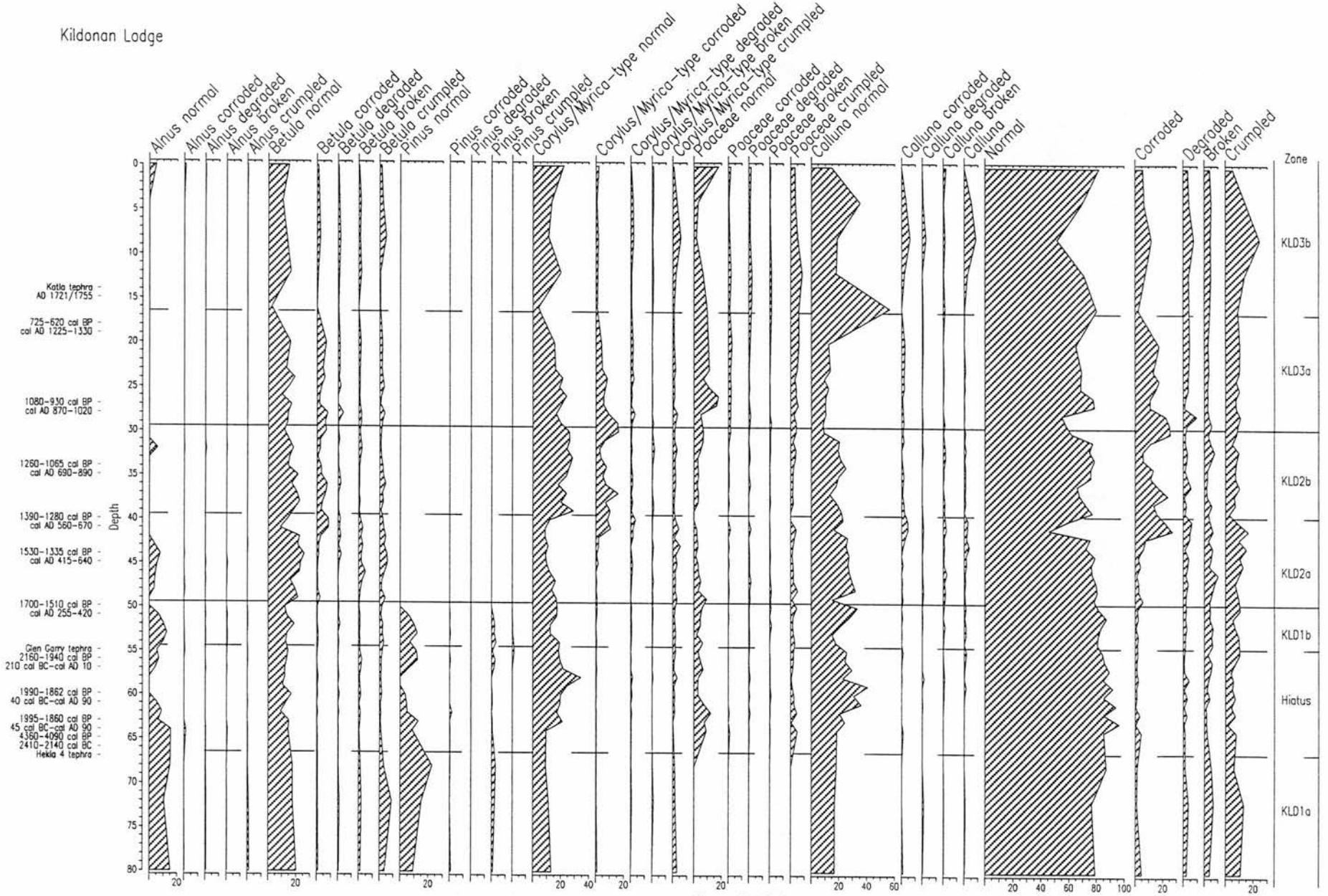


Figure 8.10. Pollen preservation.

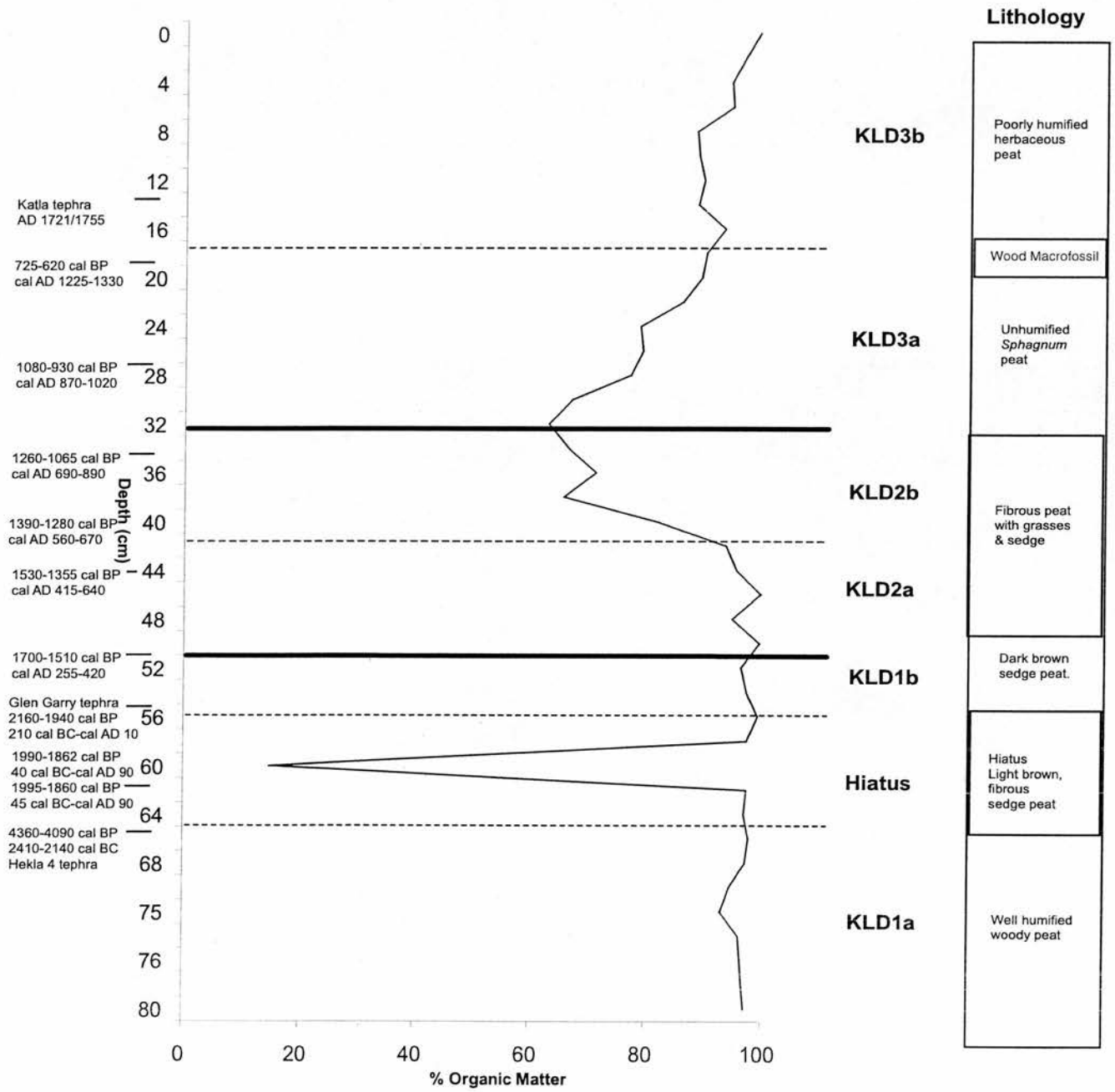
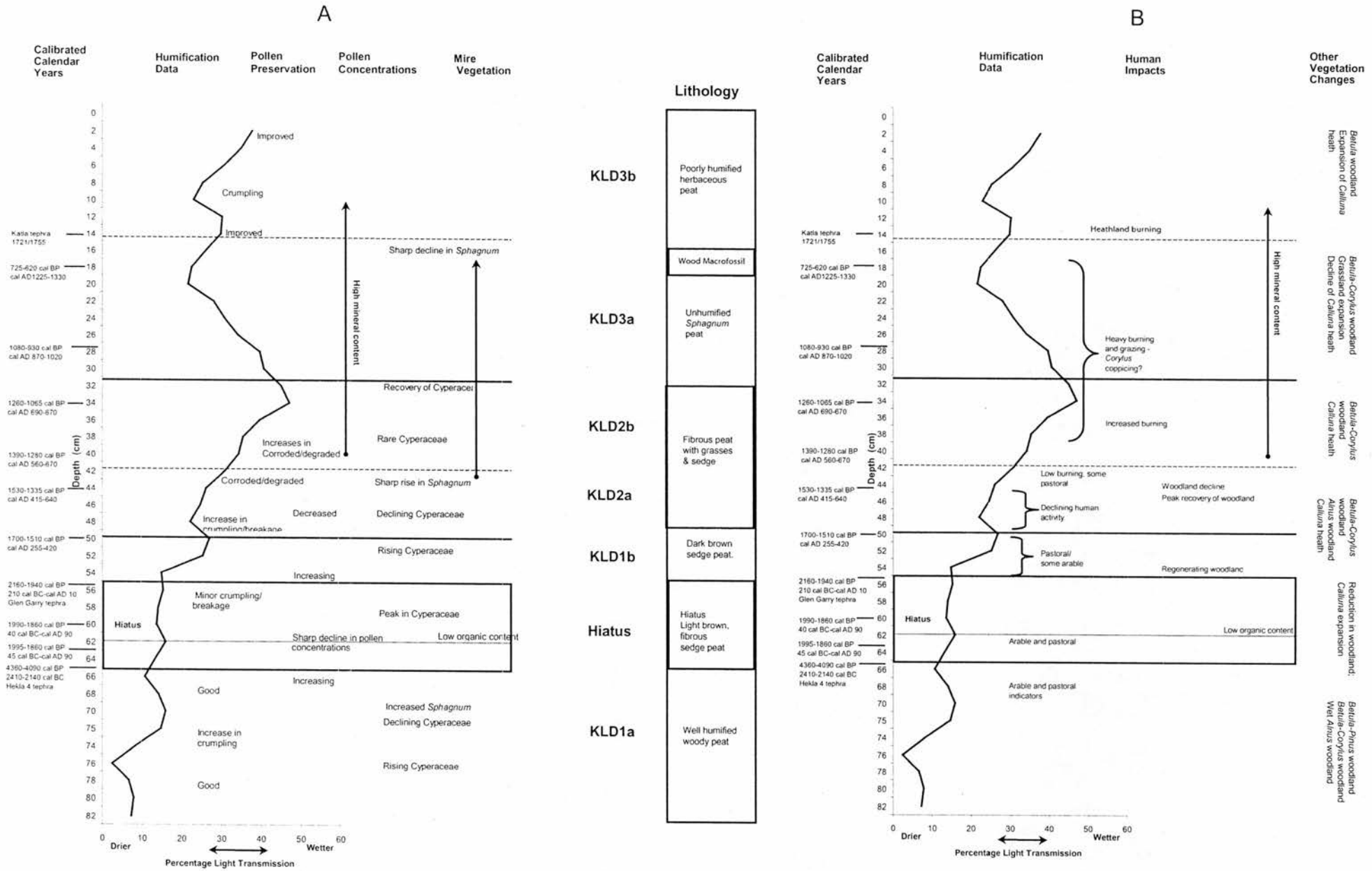


Figure 8.11. Kildonan Lodge. Loss-ignition



Figures 8.12. Palaeohydrological data, core lithology and vegetation changes for Kildonan Lodge. Figure A shows percentage light transmission plotted against depth and age with a qualitative summary of pollen preservation, concentration data and broad changes in mire surface vegetation. Figure B shows palaeohydrological shifts plotted against depth and age with a qualitative summary of human impacts and others vegetation changes.

Chapter 9

Discussion and Conclusions

"If a man began with certainties, he shall end in doubt; but if he will be content to begin with doubts...."

Francis Bacon, *The Advancement of Learning* 1605

Introduction

The theory of a Later Bronze Age catastrophe and abandonment of settlement in the Strath of Kildonan does not stand up (Figure 9.1). High resolution pollen- and peat-stratigraphic studies reflect the continuity of settlement, through the record of land-use, during and after the inferred Late Bronze Age climate deterioration *ca.* 3,160-2,870 cal BP. The methods of this investigation employed palaeoecological techniques and archaeological research to provide a broad-brush reconstruction of climate, environment and land-use in the Strath of Kildonan during the late Holocene. The results have demonstrated the scope and power for the combined use of these techniques to undertake future work to resolve the issues of settlement change and climate in the Strath of Kildonan, and in many other contexts, at increasingly refined spatial and temporal scales. The following discussion draws together the results of the investigation and examines in terms of the seven major themes, the 'premises' introduced in Chapter 1. I evaluate the failure of the theory established to explain later prehistoric settlement discontinuity and change in the Strath of Kildonan and propose an alternative perspective from which to view 'marginal' landscapes.

Late Holocene Climate Change and Human Impacts

The Early Bronze Age

The composition of the woodland at the three sites prior to *ca.* 2410-2140 cal BC (*ca.* 4,360-4,090 cal BP) was superficially, at least, quite similar. The diverse and species rich woodland was mainly dominated by pine and birch, perhaps joined by scattered rowan and poplar. On more fertile, less acid soils, birch and hazel would have formed on open woodland canopy. In areas where the water table was permanently high, such as next to lochs and along water courses, alder would have formed a wet woodland with willow. Heather, besides growing on the mire, would have colonised openings in the woodland canopy, along with bracken. In upland areas like Kinbrace Hill, where pine

was the dominant tree type, heather may have formed the main understorey component. Although the components of the three sites were broadly similar, altitude, soils, aspect and drainage significantly influenced the exact vegetation composition.

The humification records from all three sites indicate drier conditions prior to *ca.* 2410-2140 cal BC (*ca.* 4,360-4,090 cal BP). The inference of regional climatic dryness in this period is supported by palaeohydrological (Dixon, 1994) and lake level reconstructions in Achany Glen (Smith, 1998). Drier conditions at Cross Lochs around this time are thought to have encouraged the expansion of pine onto blanket peats (Charman, 1990, 1994). Drier conditions were also present on the west coast of northern Scotland between *ca.* 4,330-4,120 cal BP (Anderson, 1998). The early- to middle-Holocene is, in general, recognised as a period of comparative warmth and dryness between *ca.* 9,000 and 5,000 years ago (Cronin, 1998). Proxy climate reconstructions from NW European peat bogs indicate that the period between 5,000 and 4,000 BP was characterised by a series of abrupt oscillations between wet and dry conditions (Barber *et al*, 1994; Tipping, 1995a). A similar pattern is apparent in Wester Ross (Anderson, 1998) but appears to be absent from proxy climate reconstructions in Achany Glen (Dixon, 1994). No radiocarbon dates were available below the Hekla 4 tephra horizon for the three sequences in this study, but there are some indications at the bottom of the three profiles for oscillatory behaviour in the mire palaeohydrology.

The main difference amongst the three sites appears to be the various disturbance processes affecting the woodland cover. There is no significant woodland loss from Kildonan Lodge before *ca.* 2410-2140 cal BC (*ca.* 4,360-4,090 cal BP). Although occasional palynological indicators of human activity are detected just prior to the deposition of the Hekla 4 tephra, but these cannot be related reliably to any archaeological evidence in the catchment. The substantial loss of both birch and pine from Loch Ascaig over the course of a century or more is remarkable, and seems to be unparalleled in existing vegetation reconstructions from northern Scotland. The most probable cause is human manipulation of natural woodland disturbance and regeneration processes (*cf.* Brown, 1998; Göransson, 1988). Fluctuations in pine on Kinbrace Hill, on the other hand, appear more closely related to processes of natural fire and regeneration. In the absence of any unambiguous indicators of human activity, along with the rapid regeneration of heather and scrub in the place of pine, it seems likely that natural forest

fires were responsible for woodland disturbances on Kinbrace Hill. The differing pollen source areas of the three sites will also have influenced the recording of disturbances in the forest canopy (Chapter 5). Kildonan Lodge is a relatively small diameter basin, and as such is recording a larger proportion of local vegetation changes. Loch Ascaig and Kinbrace Hill, on the other hand, are situated on the edge of large expanses of peat. Both are recording perhaps larger or more numerous clearances further away from the mire.

At Loch Ascaig, farmers may have taken advantage of natural gap formation, or perhaps even purposively cleared areas of woodland. Individual, but spatially and temporally overlapping disturbances may have aggregated, giving rise to what appears to be a single sustained episode of woodland destruction (*cf.* Whittington & Edwards, 1998). There is no evidence that fire was involved in the vegetation changes at Loch Ascaig, suggesting slash and burn was not being practiced. Given the evidence for climatic dryness, it seems unlikely that waterlogging or paludification of soils was occurring and affecting the tree population; conditions were dry enough to allow trees to colonise the mire. Drier conditions would have encouraged natural fires caused by lightening strikes in the upland pinewoods (Tipping, 1996), such as those inferred for Kinbrace Hill. The first occurrences of anthropogenic indicator species in the Kildonan Lodge pollen profile are not associated with significant woodland disturbance. Small, temporary incursions into the woodland inferred for Kildonan Lodge are similar to those reflected, for example, in Achany Glen (Tipping & McCullagh, 1998).

It is surprising that the best evidence for Early Bronze Age human activity comes from the site with one of the lowest densities of known Neolithic and Early Bronze Age monuments, Loch Ascaig (Figure 4.1). There is only one small cairn with in 5 km. The nature of Early Bronze Age settlement is still a largely unresolved issue in many areas of Britain, and particularly so in the Strath of Kildonan. Here, Neolithic and Early Bronze Age occupation is reflected only by the presence and distribution of burial cairns. As with the Later Bronze Age, there is some disagreement over the 'sedentariness' of these early farmers (Thomas, 1991; Barclay, 1997). The lack of settlement evidence, *ie*, recognisable domestic structures has contributed to the belief that Early Bronze Age people were nomadic (Thomas, 1991). However, it has been argued because there is evidence for cultivation, houses must have existed even if not preserved in the archaeological record (Barclay, 1997; Brück, 2002; Tipping & McCullagh, 1998). In

areas where timber was plentiful, such as the Strath, structures were probably constructed from wood (*cf.* Barclay, 1997).

At Lairg it was suggested that the lack of evidence for domestic structures, despite evidence for cereal cultivation and grazing, might indicate the presence of a population of mobile agriculturalists (Tipping & McCullagh, 1998). Although slash and burn as a model for early agriculture has been rejected (Rowley-Conwy, 1981), soil exhaustion may have required the periodic take up of fresh land (McCullagh, 1998). Rowley-Conwy (1981) describes an integrated system of cropping and animal husbandry where cows provides the manure, pigs do the primary breaking and clearing of land, while sheep take care of the weeding and the fine tuning of the soil texture. However, Rowley-Conwy also rejected the need for long fallowing periods because of soil exhaustion and declining yields. The palaeoecological reconstructions in this study will not, obviously, resolve the debate about the sedentariness of Early Bronze Age farmers, nor can the precise agricultural practices be discerned, but the contrasting patterns of vegetation change between the sites are interesting in terms of the timing and distribution of human impacts on vegetation.

Just prior to the deposition of the Hekla 4 tephra, it appears that activities around Loch Ascaig were briefly abandoned. At Kildonan Lodge this marks the beginning of the hiatus in the late Holocene sequence, and the integrity of the record is not re-established until the Glen Garry tephra horizon, 230 cal BC-cal AD 10 (*ca.* 2,160-1,940 cal BP). The upland site of Kinbrace Hill still had not been appropriated by humans. The inferred abandonment of settlement around Loch Ascaig may have resulted in the regeneration of the pine-birch woodland, but re-settlement of the area a few decades later did not result in significant loss of this woodland. This only happens with the decline of pine *ca.* 2410-2140 cal BC (*ca.* 4,360-4,090 cal BP). This event is synchronous with the abrupt reduction of pine pollen in the Kinbrace Hill profile. Both are well chronologically well constrained by the Hekla 4 tephra horizon. Little can be said for the timing and significance of vegetation and palaeohydrological changes at Kildonan Lodge until after the deposition of the Glen Garry tephra horizon, except that it appears the mire was exploited for peat cutting during later prehistory.

Expansion of Settlement and Climatic Deterioration

The abandonment and resumption of agricultural activities at Loch Ascaig do not appear to be directly related to climate conditions. Abandonment took place whilst the record indicated conditions were still dry. Re-settlement, as indicated by the pollen record, occurs after the shift to wetter conditions recorded at both Loch Ascaig and Kinbrace Hill *ca.* 2410-2140 (*ca.* 4,360-4,090 cal BP). Similarly, the first indications of agricultural expansion into the uplands of Kinbrace Hill also occur after the inferred shift to wetter conditions. This shift is increasingly viewed as one of the most significant climatic changes of the Holocene (Barber *in* Tipping, 1994), recognised in many areas across the globe as a general trend of climate cooling, punctuated with complex oscillations like the Medieval Warm period and the Little Ice Age (Cronin, 1999).

The timing of the shifts in the Loch Ascaig and Kinbrace Hill sequences agrees well with the evidence from Achany Glen where increased lake levels (Smith, 1996) and a decrease in peat humification (Dixon, 1994) also coincide with the Hekla 4 tephra. The evidence conflicts with Wester Ross, where a shift to drier conditions is recorded *ca.* 4,330-4,120 cal BP (Anderson, 1998). The data from the Strath of Kildonan and Achany Glen overlap with the *ca.* 4,200 cal BP IRD event (Bond *et al.*, 1997). Anderson (1998) speculated that the Wester Ross bogs might be exhibiting a lagged response to changes in the ocean system. SSTs associated with the *ca.* 4,200 cal BP event reached their minima *ca.* 4,000 cal BP (Bond *et al.*, 1997), which coincides with the shift to wetter conditions in Wester Ross recorded *ca.* 4,020-3,630 cal BP. The apparent discrepancy in the timing of the various changes might be resolved with more precise dating, but if not, it is unclear, if these are ocean-driven changes, why inland sites should appear to be responding more rapidly than coastal sites. Arguably, this might support Bond *et al.*'s (2001) suggestion that IRD events are forced by solar-atmospheric changes, rather than changes in thermo-haline circulation (Broecker, 2001). However, it would also be expected that west coast sites would be more prone to increases in precipitation than east coast sites .

A transition to more oceanic conditions around 4,000 years ago is widely believed to be a major force behind the disappearance of pine from the region (Birks, 1972, 1975, 1988; Bridge *et al*;1900; Gear & Huntley, 1991; Huntley *et al.*, 1998). The timing of the

declines at Loch Ascaig and Kinbrace Hill, *ca.* 2410-2140 cal BC (*ca.* 4,360-4,090 cal BP0), agrees broadly with the Cross Lochs, *ca.* 4,445-4,230 cal BP (Charman, 1990, 1994) and Achany Glen where the pine decline and a shift to wetter conditions was also constrained by Hekla 4 (Smith, 1998), but is substantially later than the pine decline at near by Upper Suisgill at *ca.* 5,320-4,820 cal BP (Andrews *et al.*, 1985). The decline of pine throughout northern Scotland is, however, notably asynchronous because the timing in reductions of pine would be dependent on the nature of local conditions (*cf.* Anderson, 1998). The earlier pine decline at Upper Suisgill could be related to an earlier oscillation to wetter conditions *ca.* 5,000 cal BP, or a brief peak in *Pinus* pollen values such as the one recorded at Cross Lochs may have been missed out by the large sampling interval.

Despite making conditions more marginal for the growth of pine, the change to wetter conditions does not seem to have had a deleterious effect on agricultural activities, suggesting that 'bad for [pine] trees was not bad for humans' (*cf.* Baillie, 1998)in the Early Bronze Age. The recognition of a large scale, and possibly high magnitude transition in the North Atlantic climate system presents a serious challenge to the long standing belief that the Early Bronze Age agricultural expansion, *ca.* 2200-1800 cal BC, especially into upland areas, was a result of warmer, drier climate conditions (*cf.* Tipping, 1994). Archaeological studies in the Peruvian Andes have demonstrated that political and social tensions resulted in a response to climate change inverse to the predicted response: rather than moving downhill as conditions became cooler, people expanded activities uphill (Seltzer & Hastorf, 1990). Dincauze (2000) noted that even in studies of relatively simple systems, palaeoclimatic processes are unlikely to be an adequate, or even appropriate explanation for cultural change.

There are no clear indications as yet that social tensions contributed to the expansion of settlement into the uplands in Britain. Moreover, it is unlikely that social and political conditions would have been uniform over the whole of the British Isles (*cf.* Lillios, 1996). There is very little archaeological information available concerning this period in northern mainland Scotland. As yet, there have been no concerted attempts to re-interpret the significance of the Early Bronze Age expansion in terms of the evidence for climatic deterioration. Burgess (1985) suggests that expanding economies can survive perturbations, but others argue that expanding economies are can be highly unstable and

prone to exogenous shocks (Snooks, 1996). The data from the Strath of Kildonan serves to confirm the growing body of evidence reflecting a substantial expansion of settlement during a period of increasing climatic wetness and cooling in the North Atlantic (Chapter 2), and quite possibly a global re-organisation of the climate system.

The Development of the Agricultural Landscape

Although activity receded from the plateau at Kinbrace Hill by *ca.* 1610-1340 cal BC (*ca.* 3,360-3,370 cal BP), the pollen record indicates that burning, and perhaps some grazing and possibly cultivation continued within the larger area, and probably reflects the continuation of activities in the lowlands. In contrast, at Loch Ascaig, both arable and pastoral activities continued nearby, largely unabated. The period was marked by an unusual phase of *Salix* woodland, which may have been managed. The destruction of this *Salix* woodland *ca* 1530-1370 cal BC and the re-establishment of grazing in its place does not appear to be related to any climatic or environmental changes readily discernible in the palaeoenvironmental record. Similarly a climatic explanation for the brief episode of abandonment that followed the replacement of the *Salix* woodland with grazing is not invoked.

Instead, the destruction of the *Salix* woodland seems to mark a turning point in the relationship between people and the woodland around Loch Ascaig. After the demise of pine *ca.* 2410-2140 cal BC (*ca.* 4,360-4,090 cal BP), it was rapidly replaced in some areas by birch woodland, although other areas were kept open by grazing and cultivation. The balance between grazing, arable and woodland persisted for nearly 800 years. Small areas of woodland may have been cleared at Loch Ascaig as and when needed for cultivation or other purposes (*cf.* Tipping & McCulloch, *unpub*) and grazing may have taken place under the open cover of the birch woodland (*cf.* Groenmann-van Waateringe, 1988). The extent to which the landscape may have been parcelled out for different activities is demonstrated by the persistence of *Salix*, sensitive to both grazing and burning, while both are recorded in the record. However, during this period, indications of arable activity are generally stronger than pastoral, indicating that grazing animals may have been confined to other areas of the catchment. This apparent parcelling out of areas of the landscape may reflect the intensification of the agricultural economy (Merchant, 1989)

From *ca.* 1530-1370 cal BC the destruction of the *Salix* woodland prefigures the subsequent erosion of the birch woodland in the catchment. If management activities prior to this period were mostly passive, *ie.*, restricted to conservation measures, from *ca.* 1530-1370 cal BC onwards, human interaction with the woodland became more intrusive and seemingly more directed. There are indications that as birch was removed from the catchment, *Corylus* may have been preferentially managed, perhaps through coppicing. This is only speculation, but active forms of woodland management such as coppicing are known to have existed in southern Britain during prehistory (Rackham, 1988), and have been tentatively inferred from pollen studies in northern Scotland (*eg.* Davies, 199; Smith, 1998; Tipping & Bunting, *unpub.*; Tipping & McCulloch, *unpub*). There is sufficient evidence to suggest that by *ca.* 1530-1370 cal BC heathland was also being managed and expanded.

This apparent long term expansion and intensification (and these terms are used cautiously) of agricultural activity is not reflected in the upland site of Kinbrace Hill. Certainly, the pollen record indicates continued activity within the regional pollen catchment area, but this is rather non-specific and the record is predominantly reflecting local mire surface vegetation.

Change and Continuity: Evidence for a Late Bronze Age Climate Fluctuation and the Human Response

After *ca.* 2410-2140 cal BC (*ca.* 4,360-4,090 cal BP), the humification records reflect no distinct regional scale shifts in mire surface conditions until *ca.* 1210-910 cal BC (*ca.* 3,160-2,870 cal BP). The humification records from both Kinbrace Hill and Loch Ascaig indicate a shift to wetter mire surface conditions then. This is slightly later than shifts to wetter conditions in Wester Ross peat bogs *ca.* 3,340-3,270 cal BP (Anderson, 1998), but slightly earlier that a shift to wetter conditions recorded at Cross Lochs *ca.* 2,890-2,750 cal BP (Charman, 1990). This also overlaps with evidence for high- and mid-latitude cooling in summer temperature records from tree rings in Scandanavia (Briffa, 1994) and Ireland (Baillie, 1985; Baillie & Munro, 1988) and slightly post-dates the second Late Holocene IRD event at 3,200 cal BP (Bond *et al.*, 1997) and

As with the earlier shift to wetter conditions *ca.* 2410-2140 cal BC (*ca.* 4,360-4,090 cal BP), activities at Loch Ascaig continue largely unperturbed into the Iron age, until *ca.* 210 cal BC to cal AD 10. More remarkable is the expansion of activities into the uplands of Kinbrace Hill *ca.* 70-100 years after the shift. The evidence for pastoral activities closer to the site persists for around 200 years before again contracting. The evidence for the continued and strong indicators of agricultural activity from this investigation contrasts with Kilearnan Hill, where it is thought some non-specified agricultural activities may have continued in the Later Bronze Age (Birnie, *unpub*), as well as Upper Suisgill (Andrews *et al.*, 1985), where human impact on vegetation was only a minor and intermittent feature during the later prehistoric period.

On a broader scale of settlement and land use in northern Scotland, there have been other indications against widespread settlement discontinuity. The inland, upland settlement of Lairg in Achany Glen was abandoned *ca.* 1000 cal BC, although the pollen record indicates grazing continued around the former settlement (Tipping & McCullagh, 1998). However, in the northwest Scotland at Lochan an Druim, Birks (1980; 1993) recorded a phase of substantial woodland clearance and agricultural activity starting 1030-800 cal BC (*ca.* 2,980-2,740 cal BP) and lasting until 420-170 cal BC (*ca.* 2,370-2,120 cal BP). The agricultural intensification recorded at the Loch of Winless, Caithness comes slightly later 790-490 cal BC (2,740-2,435 cal BP) (Peglar, 1979). Both Lochan an Druim and Loch of Winless are lowland coastal sites, and evidence for agricultural expansion might be expected in these areas, especially if widespread flight from the uplands is envisioned (*cf.* Burgess, 1980, 1985, 1989). While the maintenance of activity at Loch Ascaig is perhaps not so surprising given its lower altitude, the expansion of activities into the uplands reflected by the Kinbrace Hill profiles is unexpected.

The Iron Age and Beyond

Two brief episodes of abandonment are indicated by the pollen record at Loch Ascaig during the Iron Age, the first *ca.* 600-500 cal BP and another *ca.* 200-100 cal BC, both lasting on the order of decades. From the Iron Age, the woodland at Loch Ascaig had an increasingly tenuous hold, while at Kinbrace Hill it appears to have disappeared from the plateau by *ca* 520-370 cal BC. Blanket peat vegetation, a primary feature of

Kinbrace Hill since the pine decline, may have also begun to expand outwith the mire at Loch Ascaig in the Iron Age, certainly heath moorland was increasingly the most prominent vegetation type. From *ca.* 230 cal BC-cal AD 10, activity was no longer taking place near Loch Ascaig. This period probably reflects a major re-organisation in settlement and economy associated with broch construction. By the mid-Iron Age, the sequence from Kildonan Lodge is re-established, revealing contrasts in settlement and land-use amongst the three sites during the early first millennium AD

All three sites record a shift to wetter conditions *ca.* 210 cal BC-cal AD 10 (*ca.* 2,160-1,940 cal BP). Similar shifts do not seem feature in other northern proxy climate reconstructions (Chapter 2), but there is some evidence from peat bogs elsewhere in Britain and NW Europe for wetter conditions ca. 2,320-2,040 cal BP (Hughes *et al.*, 2001). There are slight indications of changes in the North Atlantic region from marine records including evidence for cooler SSTs off the Rockall Plateau in the North Atlantic (*cf.* Duplessy et al., 1992) and also slightly pre-dates by *ca.* 200 years a pronounced cooling of SSTs in the Bermuda Rise (*cf*,. Keigwin, 1996). The patchy distribution of this shift in the record may indicate that it was not a high magnitude event or one that was sufficient to cross thresholds in a variety of locations and environments.

The 'Dark Ages'

There is some evidence of overlap in the radiocarbon ages of the Dark Age abandonment of both Loch Ascaig, *ca.* AD 330-560 and at Kildonan Lodge, just after *ca.* AD 255-420 until *ca.* 415-620. However, agricultural activity is once again apparent in the Kildonan Lodge profile, with evidence of high grazing pressure from *ca* cal AD 560-670. The abandonment of activity at Loch Ascaig persisted until *ca.* AD 685-785. The palynological evidence for sustained agricultural activity from *ca.* AD 415-620 through *ca.* AD 1220-1330 at Kildonan Lodge agrees well with the evidence from the Craggie Water investigations which suggested the construction of a clearance cairn after *ca.* AD 530-470 and ard marks dating to sometime before *ca.* AD 870-1040 (*cf.* Russell-White, 1998). At Kinbrace Hill, pastoral activities appear to have briefly expanded into the uplands *ca.* AD 250-400. Significantly, the evidence for declining activity and abandonment at Loch Ascaig and Kildonan Lodge occurs during a period of inferred drier climate conditions. A precise comparison of palaeohydrological changes between the three records is hampered, not only by the inherent imprecision of the

radiocarbon ages, but because of the much slower accumulation rate in the Kildonan Lodge core, which has compressed the past *ca.* 2,000 years into 55cm, compared to 273.0cm for Loch Ascaig and 148.0cm for Kinbrace Hill.

The onset of wetter conditions at both Kildonan Lodge and Loch Ascaig *ca.* cal AD 430-600 (*ca.* 1520-1350 cal BP) conflicts with other northern Scottish proxy climate reconstructions. At Wester Ross, Anderson (1998) reported the onset of drier mire surface conditions between *ca.* 1,480-1,340 cal BP. The NW coast data also conflicts, as Anderson notes, with the evidence for an IRD event at 1,400 cal BP, as well as evidence from other records of peat bog stratigraphy for wetter conditions (*cf.* Blackford & Chambers, 1991). The evidence for a Dark Age climate deterioration in the British Isles and the North Atlantic (Chapter 2) seems to have as patchy a distribution as the palynological evidence for settlement contraction.

There are two later wet shifts apparent in both the Loch Ascaig and Kinbrace Hill cores, but without any dating controls it is impossible to know their age or possible relationship. A shift at Kinbrace Hill can be extrapolated with a little more reliability being only 6.0 cm above the last radiocarbon determination *ca.* 1,285-1,070 cal BP (*ca.* AD 665-875). This is at odds with the data from Loch Ascaig and Kildonan Lodge which indicate the onset of drier mire surface conditions *ca.* 1490-1320 cal BP (cal AD 460-630) and *ca.* 1260-1065 cal BP (Cal AD 870-1020). Since all of these estimations have been interpolated or extrapolated, the timing and extent of 'Medieval Warm Period' conditions in the Strath of Kildonan will have to be resolved later with more precise dating.

Comparatively little is known about the archaeology and environment of Dark Age northern Scotland, making it difficult to formulate any plausible explanations for the apparent re-organisation of settlement in the Strath of Kildonan as inferred from the pollen records. More detailed information is available from southern Britain and the Anglo-Scottish Borders, where the Roman occupation had more direct impact on both vegetation and economy. For sometime, the end of the Roman occupation of Britain was viewed as period of widespread contraction of settlement and agriculture (Turner, 1981). A subsequent re-assessment of the available data has shown that evidence for abandonment in pollen records is patchy, and the withdrawal of a Roman market may

have led to an economic recession only in some areas (Dark, 2000). In southern Britain, there appears to be evidence for a contraction of settlement from altitudes over 150 m OD, perhaps in response to climatic deterioration, but the patchy distribution of land-use change has led to the suggestion that the deterioration was not severe enough to be detrimental across the whole of Britain (Dark, 2000). In Scotland, for example, at Carn Dubh, *ca.* 400m OD in Perthshire, there is evidence of expanding pastoral activities (Tipping, 1995b) whilst other lowland and island sites in northern Scotland also reflect continued or expanded activities.

Volcanic Eruptions

The deposition of a "critical load" (*cf.* Grattan & Gilbertson, 1994; Grattan & Charman, 1994) of volcanic eruptives which poisoned the soils of the Strath of Kildonan during the late second millennium BC is not reflected in the pollen record, although potential short-term effects on crop ripening or natural vegetation, of a few years at most, are not identifiable in the pollen record. Taxa such as *Alnus*, *Corylus avellana* and *Ulmus* which are not tolerant of highly acidic conditions persist at Loch Ascaig until late in the Iron Age.

Modern critical threshold data is constructed to assess the long term and persistent deposition on industrial pollutants on present day soils, and as such, is probably not appropriate for assessing the impact of single volcanic event *ca.* 3,000 years ago. Soils are generally less vulnerable to acid deposition than aquatic ecosystems and forested ecosystems, even under modern levels of acid inputs, have been shown to take a significant amount of time to respond to acid stress (Parks, 1997). Palaeolimnology studies in Britain, encompassing northern Scotland, indicate that acidity levels in lakes have remained stable over the past 12,500 years, until the onset of the Industrial Revolution (Battarbee *et al.*, 1988).

The Laki 1783 model also assumes, like Parry, that cereal growing or cultivation is the primary economic base --- if the harvest fails, so do the settlements. Young (2000) rejects the assertion that short term effects on crop ripening, if they occurred at all, would result in the abandonment of upland Britain as argued (Grattan and Charman, 1994; Grattan & Gilbertson, 1994; Grattan & Pyatt, 1994). In considering the relationship of crop growth to climate, as well as acid inputs, seasonality of potential

impacts is an important factor in determining the successful growth of crop species (ECE, 1984; Loomis & Conner., 1992). Cereals are particularly susceptible to shocks when they are flowering (Loomis & Conner, 1992).

Attempting to generalise about farming is difficult; no two farms are alike, as soils, crops, areas of land, resources, *skills* and *opinions* will vary from farm to farm (Loomis & Conner, 1992; italics added). The exact nature of the response to ecological perturbations by farming systems is not solely dependent on the environment, but by choices exercised by the farmers concerning suitable crops, fertilising, human labour and methods such as swiddening, fallowing or the use of animal traction (Bayliss-Smith, 1992). The attempt to use volcanic eruptions as an explanatory framework for settlement change, again like climate change, assumes landscapes are uniform, but the palaeoecological reconstructions here demonstrated that these three very different environments were used in different ways at different times.

Forest Regeneration

It was argued that the two extant pollen diagrams, from Kilearnan Hill and Upper Suisgill, do not provide conclusive evidence that episodes of forest regeneration reflects the Later Bronze abandonment of settlement in the Strath. In general, there is not a consistent correlation between woodland regeneration and inferred settlement abandonment in the three profiles in this study. Loch Ascaig, with its larger pollen source area, appears to be recording natural forest-heathland interactions in some parts of the landscape, superimposed on the continuation of agricultural activities in other areas. Certainly, periods of abandonment do coincide with better representation of tree pollen, but the re-establishment of activity does not always coincide with a significant reduction in trees, particularly before the Later Bronze Age. At Kildonan Lodge, woodland remained an important component of the landscape until historic times, and the local presence of woodland may be dampening the anthropogenic pollen signal. At Kinbrace Hill, the mostly open nature of the woodland even before its disappearance altogether *ca.* 520-370 cal BC means that it probably never much of an obstacle to activities such as grazing, and the appropriateness of expansion-regression models in such an environment is generally doubted (*cf.* Tipping, 1994).

Lack of ^{14}C Dates

The premise that there is a lack of radiocarbon dated settlement belonging to the Later Bronze Age was largely dealt with in Chapter 4. This demonstrated that the radiocarbon chronology of the Strath of Kildonan, far from demonstrating a settlement hiatus, actually provides very little relevant information about the occupation histories of later prehistoric settlements. The results of the palaeoecological investigations from Loch Ascaig and Kinbrace Hill provide radiocarbon dated evidence for the continuation of agricultural activities and human impacts on vegetation during the Later Bronze Age.

Population Crises

As noted in Chapter 1, testing, let alone demonstrating, a population crisis in prehistory is challenging, if not impossible, and unlikely to be a rewarding task. The results of this investigation do not address this problem directly. The assessments of archaeological evidence provided in Chapter 3 and 4 *do*, however, show that culturehistorical approaches relying on, *eg.*, literal interpretations of quantity and distribution of artefact types characteristic of southern British traditions are not applicable to northern Scotland. This interpretation of northern Britain through the "conceptualisation of a Wessex dominated past" (Bevan, 1999) has been criticised because it cannot be demonstrated that metal consumption played the same vital role in social reproduction in the north as it seems to have in the south (Harding, 2000). Approaches which attempt to estimate population based on the density and distribution of hut circle settlements, *eg.* Fairhurst and Taylor (1971) are likely to be similarly frustrated. Chapter 4 demonstrated that the chronologies and occupation histories of individual hut circles and settlements are too poorly understood to even guess at how and when structures may have functioned in relationship to each other, or at different times. The timber house from Upper Suisgill highlights the perpetual problem of archaeological visibility.

To answer the question posed in Chapter 1, — what were Bronze Age coping strategies and can their failure be demonstrated? — although to some extent potential coping strategies employed by Bronze Age people can be proposed, such as reliance on exchange and kinship (Chapters 3 & 4), their failure, and thus, the onset of a population crisis cannot be demonstrated with any degree of certainty. Taken together, the pollen evidence from Kinbrace Hill and Loch Ascaig appears to reflect an intensification and extensification of agricultural activity during the Later Bronze Age, although these terms

are used advisedly in consideration of the large pollen source areas of these two sites and their alteration over time. At Kinbrace Hill, where upland expansion consistently coincides with evidence for wetter climate conditions there is more direct evidence to suggest that economic production may have undergone temporary re-organisations in response to environmental conditions. Pollen analysis cannot demonstrate harvest failure or declining yields, but the absence of long term abandonment of agricultural activity indicates that whatever coping strategies were in place were adequate for buffering against any environmentally or socially induced obstacles faced by prehistoric farmers in the Strath of Kildonan.

Settlement Abandonment

Structures and features such as field systems are spread over large areas at all three sites (Figures 6.1, 7.1 & 8.1; Appendices I-III). The generalised picture of landscape change provided by the three investigations in this study took into account the lack of chronological information concerning the settlement record. There is no way of knowing what areas of these landscapes may have been occupied at different times. The radiocarbon dated evidence from field features in the Craggie Water catchment provides rare and useful corroborative information about Dark Age vegetation change and human impacts relating to the pollen catchment, but similar information elsewhere in the Strath is singularly lacking. Palaeoecological reconstructions can offer little insight into the length of occupation of individual hut circles. They do, however, reflect more persistent settlement than predicted in association with the density of Group 2 hut circles at Loch Ascaig. Significant, especially in the absence of any archaeological evidence of occupation at all, is the expansion of prehistoric human activities into the upland plateau of Kinbrace Hill. This could be evidence of the implementation of mobile settlement strategies, the most obvious being transhumance, but this is purely speculative.

The evidence from Upper Suisgill shows that areas formerly occupied by houses were later cultivated. Survey evidence from Kildonan Lodge and Loch Ascaig also shows that several house sites were damaged by later episodes of cultivation. The reasons for cultivating former domestic space may not have remained the same over time. The damage and destruction of hut circles in the Strath by historic cultivation may represent a sort of cost-benefit analysis on behalf of the farmers concerning the energy required to

dismantle the structures (*cf.* Halliday, 1993). Ethnographic research has shown that abandoned house sites are often farmed in order to take advantage of their exceptional fertility (David, 1971). Further investigation into site formation processes has the potential to provide valuable information concerning the re-use and re-appropriation of settlements and landscapes, as illustrated in Chapter 4.

"Reinterpreting the Margin"

Evaluating the palaeoenvironmental data from this investigation and available archaeological data for Later Bronze Age human impacts, climate variability and settlement it is tempting to apply to the Strath of Kildonan Young's conclusion that "... the Borders region provide[s] a clear example of people with a well developed sense of place... [and] established rights to land, radically reorganising their approach to production in the light of changing circumstances" (2000:77). At the moment, too little is known about the archaeology of the area to attempt an analysis of the social and spatial organisation of settlement based on Fleming's model (1986, 1988) such as that conducted by Young (2000; also Young & Simmonds, 1995,2001) to re-assess the validity of Later Bronze Age catastrophes in the Borders region. However, it is possible to speculate a little on the sort of strategies that prehistoric farmers in the Strath may have employed to enable their long term success.

Dynamic Settlement Strategies

Systems of transhumance represent an example of periodic abandonment as a land-use strategy, and usually is characterised by the seasonal abandonment and re-occupation of individual agricultural and pastoral residences (Tomka, 1996). They may take many forms. In Scotland, the traditional view is based on the system that can be traced back to medieval times. Animals were taken to higher level grazings in the summer where the family lived in dwellings called shielings. Inother parts of the world, systems of transhumance involve several dwellings used over the course of a year. Some residences may be located in areas where the family has no agricultural holdings, but are used as basis for exchange of information and goods, as well as renewing social and kinship ties. (Graham, 1996).

Stone (1996) argued that, in general, agriculturalists can rely on two distinct strategies to declining yields or harvest failure: abandonment (*ie.*, shifting cultivation) or intensification. Abandonment requires unfettered access to fresh land. Intensification on the other hand, requires the social structures necessary to mobilise labour. The existence of one system should not imply the mutual exclusion of other systems. Stone's research indicated that the two systems often operated side by side, although in some cases resulted in social tensions. Diversification is a potential 'third way'. Such an adjustment might take the short term form of relying more heavily on foods that might normally be only a minimal part of the diet, *ie.*, 'famine foods'. In the long term, diversification of crops grown might be another strategy, but requires the introduction, acceptance and cultural assimilation of new types of food (Bayliss-Smith, 1992).

If the periodic expansion of activities into the uplands is not reflecting a transhumance system, with more permanent settlements focused at lower altitudes, the palaeoecological record may be reflecting the 'predictive power' of off-site pollen analyses (*cf.* Edwards & Whittington, 1994). Areas of deep peat growth and extensive heather cover may have obscured archaeological features and structures during surface surveys (*cf.* Ray & Chamberlain, 1985) that may never be accounted for, except serendipitously. While some work has been done comparing changes in settlement patterns from mobile to different degrees of sedentariness (Rafferty, 1987), identifying mobility strategies amongst agriculturalists in the archaeological record is challenging. It is questionable whether the episodic and punctuated strategies of transhumant pastoralists and agriculturalists documented in ethnographical studies could be differentiated from each other in artefact assemblages (David & Kramer, 2001). It is stressed that archaeologists require a substantial amount of data to recognise variations in artefact assemblages of different types of abandonment (David & Kramer, 2001; Nelson, 2000 Graham, 1996; Stone, 1996) highlighted in Figure 1.12.

Re-thinking Marginal Environments in The Strath of Kildonan

Although not strictly speaking consideration of a strategy, archaeologists may have to alter their perspective of prehistoric landscapes in order to better appreciate how they were lived in. It is recognised that farmers could 'micro-manage' vegetation and soil variations to their advantage (*cf.* Davies, 1999), but they may have exhibited selectivity on larger scales, and in directions not anticipated by traditional views of Highland

landscapes. Figure 5.1 illustrates the stark contrast between the rich green of the haughland and the dull brown of the peatlands. Today, the fertile alluvial soils of the Strath may seem the most desirable place engage in agriculture. However, until the development of hydroelectric schemes and other water development work which tamed rivers, the floors of Highland straths and glens were seen as treacherous places. The frequency and unpredictability of flooding meant that farmers were generally unenthusiastic about putting time and effort into improving these areas (Bil, 1990). Historical documentation demonstrates that the Helmsdale River often flooded, sometimes with catastrophic results.

In the 18th (1791-1793) century Statistical Accounts of Scotland, the Reverend Sage remarked that,

> "Inundations of the River Helmsdale with floods in summer and harvest time often become fatal and destructive in the Strath of Kildonan; and the tenantry, whose lands lie flat and low along the water, have their corn and hay carried down by the stream. By means of these inundations, the river has changed course and detached several fields on each side from the farms to which they formerly belonged."

He went on to recount the following incident:

> "In Breincheol, a shieling or grazing in this parish happened to fall a dreadful water spout about 40 years ago. The Bowman, with his family, and the produce of the dairy, were all carried away in one heap, in the hut or booth where they slept that night... the course, which the tremendous stream marked out, may be computed at 60 or 80 feet deep." (*Stat. Acct., 1791-97*)

In 1810, William Young, factor to the Sutherland estate, remarked in his diary that the lowest grounds were sometimes flooded by the Helmsdale River (Adam, 1972). Henderson (1812) noted that the tenant farmers in the Strath of Kildonan did not manure the land on the valley floor, believing that it made the soil looser and more prone to being carried away by the floods. In 1845, the Rev. Campbell, remarked in passing that, "It [the Helmsdale River] receives its waters from some lakes in the upper part of the parish, and from many mountain streams which swell its stream in all parts of the course." (*2nd Stat. Acct.*, 1845). Bil (1990) suggests that a significant part of the reason highland economies concentrated on pastoralism rather than arable production, was this permanent threat of having crops and land carried away, rather than climatic limits to growth.

Erosion was a persistent occurrence at Upper Suisgill (Barclay, 1985), but does not appear to have deterred settlement. The absence of any significant mineral inputs into the sediment as indicated by the loss-on-ignition data from Loch Ascaig and Kinbrace Hill (Figures 6.10 & 7.9) may indicate that mineral soils surrounding the site were already effectively sealed by a layer of peat by the Late Holocene (*cf.* Bennett *et al.*, 1992). For most of the Medieval and Early historic period, erosion appears to have been a significant process at Kildonan Lodge. There is some debate about upland erosion in Britain as a product of climate change or human influence (*cf.* Ballantyne, 1991). In the Strath of Kildonan, it may involve a little bit of both. The erosion of minerogenic material into the sediments of Kildonan Lodge comes at a time of both inferred climate wetness and intensive grazing. In pastoral economies, erosion may not necessarily be viewed as process which makes land more marginal; ethnographic studies have shown that erosion is seen as an acceptable by-product of grazing (van der Leeuw, 2000).

Clearly, fluvial activity was a significant factor in decision making and land use in the Strath of Kildonan within the past 250 years. The seeming lack of prehistoric settlement along the floor of the Strath was thought to be of the of technology to adequately drain the valley floor (Fairhurst & Taylor, 1971). However, the behaviour of the river system may have also influenced the apparent absence of prehistoric settlement along the valley floor. Erosion of sediments on the valley sides, reflected at Upper Suisgill and Kildonan Lodge was also important, but it is difficult to evaluate potential causes or influencing factors. Intense grazing pressure may have contributed to some extent (Chapter 8, also Barclay, 1985). Investigations are needed into the Holocene geomorphological development of the Helmsdale River catchment to evaluate the importance of fluvial activity and other geomorphological processes during prehistory, in terms of their relationship to both climate and human occupation.

The Landscape 'Mosaic'

It is clear that settlement continued in the Strath of Kildonan as a whole almost without interruption from the Neolithic/Early Bronze Age until the present day. The picture is not so clear concerning the early first millennium AD, but this will need to be resolved with further archaeological and palaeoenvironmental research. It seems reasonable to conclude from the evidence presented that each site was used in different ways at different times. This may have arose from changing needs and perceptions of the

landscape by different farmers. After the initial expansion of arable activity and improved grassland in the Early Bronze Age at Kinbrace Hill, it seems that the area was largely relegated to pastoral exploitation. The picture of from Loch Ascaig is different again. At various times the emphasis on arable, potential woodland management and pastoral activities involving both the maintenance of grassland and management of heathland, is altered. At Kildonan Lodge, heathland management is not apparent until Medieval times, which parallels the situation at nearby Kilearnan Hill (Birnie, *unpub*). Both the 'blacklands' and the 'greenlands' would have played an integral role in the economic and social life of farmers in the Strath through time, not just in terms of grazing and cultivation, but for the collection and manufacturing of items necessary for everyday life, perhaps for exchange for goods and labour from other settlements.

'Greenlands'

'Greenlands' would have supported cultivation of crops and improved grazing (Tipping & McCullagh, 1998). It is clear from archaeological evidence from other excavations, but also from the survey evidence in the Strath of Kildonan, that farmers actively engaged in altering this environment to suit their purposes for arable production. This evidenced by the constructions of various walls, banks and ditches. Substantial lynchets are often found in the field systems. The survival of evidence in these areas *is* generally poorer because of successive periods of intensive use (*cf.* Halliday, 1993). There are no indications of the mix of crops, cereal-type pollen has been found in all of the pollen profiles from the Strath (*cf.* Andrews *et al.*, 1985; Birnie, *unpub.*; this investigation), but there macrofossil evidence still raises some doubts about the presence or extent of cereal production (*cf.* Van der Veen *in* Barclay, 1985).

'Blacklands'

Heather (*Calluna vulgaris*) from the 'blacklands' was used in prehistory for making rope, baskets, bedding, flavouring alcoholic beverages and as a dye (Dickson & Dickson, 2000). Rushes (Cyperaceae) and bracken (*Pteridium aquilinum*) were also used as thatching. Mosses (*Sphagnum* spp.) were used as packing for wounds into the 20th century. Bog myrtle (*Myrica gale*) was used to make antiseptics, astringents, dyestuff (Skene *et al.*, 1999), as well as being used as fodder for goats (Wijngaarden-Bakker, 1998). Peat turves could be burned or used 'raw' as manure, as fuel and as roofing or walling material (Carter, 1998; Dickson, 1998). Peatlands would have also

provided grazing resources in prehistory, as in the modern day. There is not yet any direct evidence for peat cutting in the Strath. Peat stratigraphic and pollen evidence (Chapters 6 and 8) indicate that the mire surfaces were disturbed in some way during later prehistory, but the exact mechanism and purposes cannot be defined with any certainty.

In historic times, it was observed that shepherds in Sutherland exploited different niches in the landscape for their flocks depending on the time of year (Sellar, 1831). Sellar described how, the wet months from October to January, shepherds sought out drier knolls of heather on which to feed their flocks. Adjacent to these areas of drier heather, on deeper, damper peats, sheep grazed on *Eriophorum vaginatum* (cotton grass), *Carex cæspitosa* (lesser tufted sedge) and heather during the autumn and winter. From February to April, *Carex panicea* (carnation sedge), *Juncus squarrosus* (heath rush) and *Eriophorum vaginatum* were important, but from April to mid-May there could sometimes be lag in suitable food until the summer pastures were ready. In exposed situations, shepherds burnt the heather, so sheep could eat the young shoots in August and September . *Eriophorum vaginatum* was particularly prized by shepherds as nutritious food during lambing time (Adam, 1972).

While the particular patterns of natural resource exploitation outlined above cannot be demonstrated from the present data, it further highlights the folly of assuming landscapes are uniformly marginal or uniformly unproductive. The palaeoecological reconstructions from all three sites indicate that the mire surface played a role in the agricultural economy at various times in the past. This raises particular problems when it comes to using mire surface vegetation assemblages to support interpretations of humification data. At Loch Ascaig, and to a lesser extent Kinbrace Hill and Kildonan Lodge, changes in mire surface vegetation appear to be more closely related at times to evidence for burning and grazing than evidence for palaeohydrological change.

Areas within the 'blacklands' appear to have also been adapted for arable activity at times. The most visible example in the Strath are the frequent surviving patches of cord rig, particularly around Loch Ascaig, although their precise date is unknown, they are generally believed to originate in the second millennium (Topping, 1989). Ridging is one method which can be used to improve soil quality through better drainage and

increasing the soil temperature (Gallagher, 1989; Topping, 1989). Experimental work has shown that similar practices in Faeroes, called *reinavelta*, have been shown to raise soil temperature by 1-1.5°C and extend the growing season by up to one month (Christiansen, 1996). Manuring, using peat turves, could have also been practiced in the Strath of Kildonan, as evidenced at Lairg (Carter, 1998), but this needs further investigation.

Heathland Management

The Later Bronze Age at Loch Ascaig sees an increasing emphasis on pastoral activities, in particular it is argued that by *ca.* 1530-1300 cal BC onwards heathland was being managed with fire. At Kinbrace Hill, this occurred slightly later *ca.* 1130-920 cal BC. At Kildonan Lodge, much later again, *ca.* cal AD 1220-1330 Edwards (1999) has pointed out that the creation and maintenance of heathland by Mesolithic populations for grazing has long been a debated topic in palynology. In Scotland, Edwards *et al.* (1995) indicate that the expansion of *Calluna* heath on the Hebridean Island of South Uist is linked 'circumstantially' to fire, as indicated by the microscopic charcoal curve, at various times throughout prehistory. Besides the circumstantial link between increased frequency of microscopic charcoal and the abundance of *Calluna* pollen, at Loch Ascaig, elements of succession described from neo-ecological studies of muirburn can be detected in the pollen diagram. For example, the succession to other ericaceous shrubs and grasses after burning (Gill & Groves, 1983), the increased abundance of *Potentilla* after some episodes of burning may be due to its resistance to fire (Gimingham *et al.*, 1983) and the re-establishment of woodland when burning and grazing appear to be relaxed (Gimingham, 1972; Legg, 1995). The abrupt and profound reductions in *Calluna* recorded at times may be related to the reduction in the abundance of *Calluna* plants which can persist for up to twenty years after burning (*cf.* Miles, 1986).

Why was there a change from an agricultural approach involving aspects of woodland, arable, improved and rough grazing to this emphasis on open, pastoral landscapes? The replacement of woodland by open areas such as heathland or grass pasture may have become increasing crucial to increasing the numbers of livestock (Gimingham *et al.*, 1983). Alternatively, Odgaard (1992) suggested that muirburn at Skansø, Denmark was implemented when soils became too acidic and nutrient poor to make the maintenance

of improved grassland worthwhile. The change in economic perspective might be related to the climate and environmental changes far removed in time from the Later Bronze Age. The palaeoenvironmental reconstructions from both Loch Ascaig and Kinbrace Hill indicate that the onset of wetter conditions apparent from *ca.* 4,360-4,090 cal BP persisted to some extent afterwards. It should be stressed that many palaeoclimate researchers see the transition to the late Holocene as a switch to significantly cooler and wetter conditions, setting it apart from the warmth and dryness of the Mid- and Early-Holocene (Cronin, 1999). This may be classed as a large magnitude shift, beyond previous boundaries of Holocene climate variability, into a new state (*cf.* Dean, 2000).

If the suggestion of a transition to more oceanic climate regime after *ca.* 4,360-4,090 cal BP (Huntley *et al.*, 1998) is correct, , increased precipitation and milder winters would have promoted gleying of soils in poorly drained areas and leaching on better drained soils elsewhere in the catchment (*cf*, Crawford, 1988). Heavy burning and grazing would have promoted nutrient depletion and acidification (Legg, 1995), whilst 'poaching' of soils by livestock (Batey, 1988) and burning (Malik *et al.*, 1984) would have reduced soil porosity, further encouraging waterlogging and gleying. The more extensive loss of trees at Loch Ascaig from *ca.* 1130-920 cal BC and Kinbrace Hill *ca.* 520-370 cal BC would have further altered the hydrological balance of the catchments through reduced evapo-transpiration. The replacement of *Betula*, which can maintain or even enhance soil pH (Miles, 1985) by *Calluna* would have further contributed to soil acidification (*cf.* Gimingham, 1981). By the Later Bronze Age, in more 'marginal' areas such as Loch Ascaig and Kinbrace Hill, the management of heathland, as suggested by Odgaard (1992) for Denmark, may have become the most tenable strategy on which to focus agricultural production.

Exchange

Although little can be inferred from the sparse material evidence and the generally poor contextual information associated with them, the presence of shale objects and ceramics with steatite inclusions signals, at the very least, the interaction of the prehistoric economy of the Strath of Kildonan in the wider region. Whether exchange was organised along kinship or other lines, there remains the possibility that exchange was used as a strategy for coping in times of environmental stress. Even if harvest failed

'catastrophically' in the Strath of Kildonan over a season or two, there is no reason to believe that the entire region would have been similarly affected. As late as the 19th century, the Strath of Kildonan depended on Caithness for grain imports when the local harvest failed (Adam, 1972). Some have envisioned exchanges of labour between settlements not just as a means of coping with scarcity, but as a general approach to production (Davies, 1999; Fleming, 1988; Young & Simmonds, 2001), although others continue to maintain that individual settlements were self-sufficient.

The Later Bronze Age represents an intensification of both arable and pastoral activities at Loch Ascaig for a short time before giving way to mainly pastoral. The picture obtained from Kinbrace Hill is much more fragmentary. Certainly, there is evidence that the upland plateau was exploited as a resource for grazing perhaps in response to external stimuli such as climate. However, was this also accompanied by the intensification of arable activities at the settlements of Kinbrace or Creagan nan Caorach? Would an investigation into the upland areas around Loch Ascaig reflect the expansion of pastoral activities similar to that seen at Kinbrace Hill? Vegetation reconstructions from paired upland-lowland sites would help to shed some light on the question of just how self-sufficient or integrated settlements were in the Strath of Kildonan as well as perhaps elucidating the relationship of lowland settlements to their surrounding uplands.

It has also been suggested that the interior uplands of Sutherland would have been a valuable source of livestock and timber in later prehistory (Cowley, *unpub*). Again, there is little to support this suggestion one way or another from this investigation. However, there is an interesting historical anecdote as regards the potential trade of timber in prehistory, if not entirely admissible as evidence. In the late 18th and early 19th centuries Captain J. Henderson was sent to Sutherland to make a case for the 'improvement' of the estate. His finished work, "*General view of the Agriculture of the county of Sutherland with Observations to the Means of its Improvement*" (1812), presents a thorough and enlightening description of the character of agricultural life in northern Scotland before the Clearances. He recounted an incident where 30 pine logs placed close together and in tiers were discovered under two feet of peat within a half mile of the Halladale River. Henderson speculated that the timber had been cut to be floated down the river to Tor or

Bighouse Bay [now Melvich Bay] on the north coast to be exported or carried further along the coast, sometime in Scotland's prehistoric past.

Other Strategies

Other strategies known from other archaeological contexts or historical practices are probably lost to the archaeological record. There is disagreement over whether or not calf slaughter, represented by a high proportion of the remains of immature animals on archaeological sites, signifies exclusive dairying practices or the keeping of cattle for both meat and dairy products (Clutton-Brock, 1981; Legge, 1981). In both the Western Isles (McCormick, 1998) and pre-Clearance Strath of Kildonan (Henderson, 1812), it was usual to keep one calf between two cows, because of the difficulty of keeping two calves alive while obtaining milk and milk products for human consumption. In times of scarcity, it was recorded that tenant farmers in the Strath of Kildonan would bleed the cattle, and boil the blood for consumption (Henderson, 1812), a practice likely to remain undetected archaeologically, unless preserved as residue on pottery.

Only the excavation of the Upper Suisgill settlement offers an indication that wild sources of food, *eg.*, hazelnuts, were exploited in later prehistory (van der Veen *in* Barclay, 1985). The Helmsdale River is today known as one of the finest (and most exclusive) areas for angling in Scotland. Despite the lack of archaeological evidence, it seems unlikely that this source of food would have gone unnoticed or unused. To this can be added plentiful deer, grouse and other birds or fowl. The excavations of the Crosskirk broch, although later date, in Caithness indicated that wild animals made up a significant portion of recovered animal bones (Fairhurst, 1980). This is at odds with southern British evidence from roughly the same period where wild animal remains often make up less than 1% of faunal remains at individual and are usually interpreted as ritually significant (*cf.* Hill, 2001). It seems likely that hunting, fishing and gathering would have remained an important part of the later prehistoric economy of the Strath of Kildonan, perhaps to be relied on more heavily when harvests were poor.

Conclusions

The results of the palaeoenvironmental investigations at Kinbrace Hill, Loch Ascaig and Kildonan Lodge do not support the theory that climate changes during the past 4,000

years were detrimental to marginal agricultural settlements in the Strath of Kildonan. Besides the Later Bronze Age shift to wetter conditions *ca.* 1210-920 cal BC (*ca.* 3,160-2,870 cal BP), three other regionally significant shifts to wetter conditions are recorded at *ca.*2410-2140 cal BC (*ca.* 4,360-4,090cal BP); *ca.* 210 cal BC- (*ca.* 2,160-1,825 cal BP) and 1,520-1,350. There are two other potential shifts *ca.* 1,285-1,050 and *ca.* 730-625 cal BP, but these need to be resolved with further dating and palaeoclimatic reconstruction. Although synchroneity cannot be categorically demonstrated, these inferred shifts reflect parallels in other proxy climate records in the region.

The late Holocene climate as indicated by the proxy reconstructions in this study, and other regional reconstructions indicates a highly variable climate. As discussed in Chapter 1, it is believed that humans are best adapted to frequent variability. In particular, it has been suggested that agro-pastoral economies, perhaps similar to those inferred for the Strath of Kildonan, are ideally suited for areas where climatic and environmentally uncertainty is a recurrent phenomenon (Crumley, 1996), presumably because of the wide resource base afforded by a mixed-farming strategy (*cf.* Halliday, 1993). It is possible that the search for a climate change or a volcanic eruption which could 'explain' cultural and settlement change during the Later Bronze Age has been somewhat of a red-herring. There are no indications, as yet, that late Holocene climate variability extended beyond any range on normal variation that could be anticipated or was beyond the extant strategies of prehistoric farmers.

There is no evidence from palaeoecological data which supports the long term abandonment of agricultural activities in response to inferred climate changes. Significantly, the two most marginal areas, Loch Ascaig and Kinbrace Hill, where settlement and agricultural production were most likely to have been abandoned, reflect continued human activity in the pollen profiles. The palaeoclimatic reconstructions from both sites reflect evidence for a shift to wetter conditions *ca.* 2,870-3,160 cal BP, but the pollen record does not reflect the long term abandonment of Loch Ascaig following this shift, and at Kinbrace Hill, the shift is followed by expansion of activity into the uplands. There are no indications in the proxy climate reconstructions of a shift in climate conditions *ca.* 2,650 cal BP which has been linked to global scale climate change and settlement failure (*cf.* van Geel *et al.*, 1998; van Geel & Renssen, 1998).

There is, I believe, a more sound basis for suggesting that the 'switch' to Late Holocene climate conditions would have precipitated a more visible and perhaps singular adaptive responses from prehistoric populations. However, the impact of this may have been mediated in the long term through environmental changes such as those described above, as well as of trial and error on the part of people adjusting to changing conditions (*cf.* Dincauze, 2000). The whole of the Earlier and Later Bronze Age may represent a period of adjustment, onto which is superimposed innovations such as bronze production and exchange, the introduction of new crops and technologies, internal social changes, influences from other European contacts, or any number of processes which would vary in importance from region to region. Attempting to demonstrate this in the archaeological record might not be directly possible. Improved understanding of the mechanisms which force climate change, the ability to reconstruct change quantitatively and a more detailed understanding of later prehistoric settlement in 'marginal' areas would definitely be an important first step in resolving key problems.

The results from the this investigation do not support the theory of Later Bronze Age settlement discontinuity during the Later Bronze Age, either as a result of climatic change or Icelandic volcanic eruptions. They both challenge environmentally deterministic interpretations and also highlight some of the ways which culture and cultural adjustments provide strategies for coping with times of uncertainty and scarcity. Humans possess unique abilities in the ways in which they perceive, process and transmit information in order to make informed decisions (van der Leeuw, 1997). Future excavation of archaeological sites in conjunction with strategically implemented palaeoenvironmental programmes should be directed towards elucidating the dynamic relationship between subsistence, social reproduction and environment in 'marginal' landscapes by conceptualising them as "...not merely containing a lot of potentially related sites, but as the matrix within which past life has been enacted..." (Fowler, 1995).

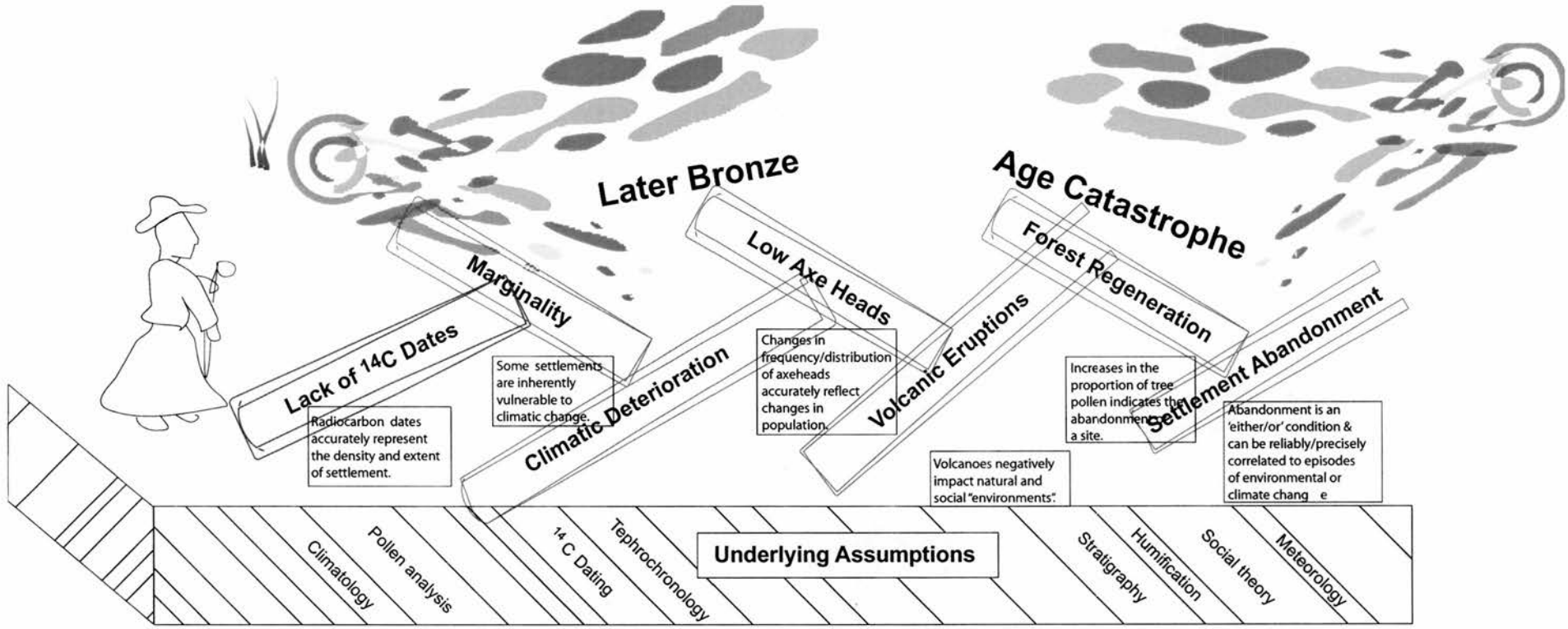


Figure 9.1 The Remains of the Later Bronze Age Catastrophe.

Epilogue

Issues and Avenues for Future Research

The results of this research have highlighted a number of issues and presented several avenues for future research, both substantive and methodological, and are relevant to any number of geographical and chronological contexts:

Palaeoecological investigations indicate that prehistoric farmers modified and managed their environment, as well as stimulating unusual and unexpected changes in the structure of vegetation. Work needs to be undertaken to identify the geographical extent of these changes and the ecological implications. In the context of the Strath of Kildonan, it appears that heathland management and woodland conservation may have been two of the primary forms of managing the landscape. But the question remains whether the implementation of these strategies was induced by environmental/climatic impacts or linked to transformations in socio-cultural structures. Investigating the potential long term 'natural' development of landscapes *versus* anthropogenic manipulation also has contemporary political implications regarding debates about the restoration of 'natural' woodland or the importance of heathlands as a 'natural' resource. Future investigations of paired upland and lowland sites might also help elucidate potential transhumance activities or other ways in which apparently unoccupied upland areas may have been exploited by neighbouring lowland farmers.

The scenario of a Later Bronze Age catastrophe has engendered a lively debate in both the archaeological and palaeoecological literature. Despite this, there continues to be in many circles, a reliance on simple, descriptive 'explanations' of change couched in environmentally deterministic language. However, simply identifying the presence or absence of certain phenomena in the records is not enough. Results from the Strath of Kildonan indicate a poor correlation between regional palaeoclimatic shifts and land-use changes or settlement abandonment as reflected by the pollen record. This raises the crucial question of how to identify when statistical evidence for significant climate change converges with the subjective recognition of people. To answer this requires integrative archaeological and palaeoenvironmental programmes.

Archaeology can contribute by turning research towards identifying socio-cultural mechanisms which might shape perception, decision-making, resource allocation or implementation of adjustment strategies. To carry this out effectively, however, requires more active dialogue between archaeologists and palaeoenvironmental researchers and might include a more considered and context specific approach to the concepts and language used to frame interpretations of human-environment interactions., *eg.*, marginality, core-periphery relationships, catastrophe and degradation. Ethnographic studies of aspects such as subsistence, decision-making and perceptions of landscape and climate in marginal areas might also help direct future archaeological investigations.

Archaeological survey of the Strath of Kildonan has identified no settlements that can confidently be assigned to the early first millennium AD. While the results from Loch Ascaig support the inference of a lacuna in settlement, both Kinbrace Hill and Kildonan Lodge reflect continued settlement. This has two important implications. Firstly, it highlights the so-called 'predictive power' of off-site pollen analyses. Future archaeological work should be directed towards investigating Dark Age settlement patterns and resolving the apparent disparity between the pollen record and the archaeological record. In addition, the nature of subsistence and settlement during the Medieval and post-Medieval periods is poorly understood in Scotland, but also in many parts of continental Europe. Integrated palaeoenvironmental and archaeological programmes can be implemented to address issues of recent environmental and cultural change during the past 500 years.

Currently, work is underway to develop testate amoeba as a proxy indicator of water table depth in peatlands in an effort to quantify humification data. However, this technique can only be applied on *Sphagnum* peats (Jackson, *pers comm.*) which would exclude the predominantly sedge-grass peats in this study. This investigation has shown that humification studies are a robust techniques for indicating the general wetness or dryness of the mire surface, but its value in extrapolating this information to human experience is hindered by several factors. Lack of quantification means that the magnitude of shifts cannot be reconstructed reliably. Imprecise dating is one of the major limiting factors in identifying climate system links and forcing mechanisms. A major assumption is that palaeohydrological changes in wetlands reflect dryland

changes, and that these are equivalent. The potential influence of 'vital effects' on records of peat humification has been recognised for some time. The results of the palaeoenvironmental investigations in the Strath of Kildonan indicate that a more rigorous assessment needs to be made of the implications of grazing, burning and peat cutting on mire surfaces for the construction of reliable and continuous records of palaeoclimatic change. Although pollen reconstructions of mire surface vegetation have been used to support inference about mire palaeohydrology, the results from this investigation indicate that at times changes in the mire surface vegetation are more closely linked to human activities than changes in the humification curve.

Tephrochronology is a valuable and powerful tool for intra-site comparison of palaeoenvironmental sequences, but in Britain the techniques is not yet well developed enough for tephra horizons to entirely replace the need for AMS or other radiometrtic dates. In order to constrain the variable sedimentation rates of peat records, and therefore reliably interpolate the age of vegetation and other changes, the most precise and accurate methods must be used. The results if this investigation highlighted some issues regarding the wide age range associated with the Glen Garry tephra which need to be resolved in order to make it a more effective tool in palaeoenvironmental reconstruction. The Kildonan Lodge profile revealed the presence of a basaltic tephra, Katla 1721/1755. Further work on this tephra would provide a useful chronostratigraphic marker in the period of time before ^{210}Pb becomes effective dating tool.

Appendix I

Loch Ascaig

Loch Ascaig, although lower in altitude, is very exposed and blanket peat formation is extensive. The landscape around Loch Ascaig is more uniform than Kildonan Lodge, with limited occurrence of fluvial and glacial features. The archaeology of Loch Ascaig does not reflect early settlement comparable to near Kinbrace hill, for example; there are two round cairns, probably early to middle Bronze Age, the nearest in Abhainn na Frithe, the other 5km to the west (Figure 4.1). Later periods of settlement are represented by hut circles, burnt mounds, souterrains, brochs and farmsteads. The dominance of Group 1 and 2 (Figure 4.2) hut circle sites in the vicinity is suggested to represent more intermittent and less intensive occupation that at Kildonan Lodge (RCAHMS, 1993; Cowley, 1998).

One of the hut circles in the area was excavated by Curle in 1910 (RCAMS, 1911; Curle, 1911). The hut (NC 8325 2562) consists of two stone banks 1.5m apart, joined by an entrance passage. The outer circle is constructed of compacted earth and stone, and the inner circle of rubble, and is roughly faced. A hearth was found in the centre of the hut. Although Curle (1911) originally believed that this structure was constructed with double walls, subsequent re-survey indicates it probably represents two separate phases, with a later, smaller house inserted into the earlier, larger one (RCAHMS, 1993). A saddle quern was found during the original excavation (Curle, 1911). Traces of a small rectilinear structure were found near the entrance, function unknown. This hut and the 4 that accompany it are set within a field system of approximately 7 ha, marked only by scattered clearance heaps.

Several of the hut circles are associated with external 'baffle walls' which appear to be protecting the entrances (RCAHMS, 1993), *eg.* NC 8427 2539 and NC 8438 2526. A rare, and badly damaged, double-celled type hut circle is recorded (NC 8332 2561), which may conform to Harris' (1984) tangential type (Table3.1), although she cautions that excavation is the only means of assessing accurately the morphology. In the

immediate vicinity of this hut circle is one whose entrance terminals end in projecting horns (NC 8325 2562); it also appears to have the remains of a field wall extending out from it. Several of the huts have been constructed on platforms scooped out of the hillside, *eg.*, NC 8437 2719, which also has an associated lynchet. NC 8332 2561 shows two visible structural phases: The first is a 9.3m diameter hut, part of which has been overlain by a later oval feature 8.5m in diameter. In general, the NMRS data indicates that the hut circles in this area are poorly preserved; it was noted that the area around many of the huts bore the signs of more recent cultivation activity.

While the only evidence for cultivation associated with some of the hut circles is clearance heaps (*eg.*, NC 8146 2592), others are accompanied by better defined features. Associated with the groups of huts located at NC 82 NW 8 843 253 are a cluster of small cairns, a fragmentary bank and, close to hut NC 8427 2539, is possible cord rig. A burnt mound (NC 8457 2533) is also set to the side of small burn which drains into Loch Ascaig nearby. Cord rig has also associated with Group 2 and 3 settlements in the northern part of the Srath na Frithe (Figure 5.2). The encroachment of peat may mask further evidence of cord rig (RCAHMS, 1993). A free-standing souterrain (NC 8447 2527) has an entrance emanating from a mound adjacent to a group of hut circles. The structure is marked by a lintel and a rectangular depression in the ground is though to follow the line of the souterrain. Presumably it relates to the occupation of one or more of the hut circles in the cluster, but without further investigation, the temporal relationship of the souterrain to other structures, including the brochs, is conjectural.

The nearest broch (NC 8433 2733) is about 2.0km north of the Loch Ascaig hut circles and is one of the better preserved brochs in the Strath (Figure 4.2). Five intramural chambers are discernible, along with the remains of an intramural stair. The entrance and guard cell are still in place and the broch is intact up to a height of 1.2m, although it has been substantially robbed and is filled with rubble. No defensive works are apparent. Three kilometres to the west of Loch Ascaig are the remains of a broch at Altnaduin, which was mostly dismantled in the late 19th century. Most of what remains are the

Appendix II

Kinbrace Hill

With the exception of Caen Burn in the southeastern reaches of the Strath of Kildonan, the lower slopes of Kinbrace Hill and Creag nan Caorach exhibit the highest density of cairns (Figure 5.2). Although most burnt mounds occur in isolation, at Kinbrace, there are three burnt mounds (NC82 NE 53) located within 30m of each other (RCAHMS, 1993). The nearest broch appears to be located about 3km away, on the northern bank of the Helmsdale River and around 1km from Suisgill Burn. While the slopes of Kinbrace Hill and the surrounding area exhibit a wide range of prehistoric structures and features, the area differs from Loch Ascaig and Kildonan Lodge in terms of the shielings associated with it. These are situated at higher altitudes and are removed from any obvious signs of prehistoric settlement activity and are probably associated with KinBrace township and the two townships recorded near Achentoul, to the north.. Two potential corn drying kilns were found in the vicinity of the main area of settlement (NC 866 295). Many of the structures and features on the SW facing slopes of Kinbrace Hill have been heavily damaged by afforestation, the extent of which is apparent from Figure 5.3.

The main area of prehistoric settlement is situated on the western slope of Kinbrace Hill (*ca.* NC 866 295). Using Kilphedir as an analogy, it is speculated that this settlement reflects two phases of activity (RCAMS/CANMORE). The first phase is characterised by simple single walled hut circles and is ascribed to *ca.* 500 BC. The second phase is marked by the appearance, or possible a renovation of an earlier structure, a massively built hut which appears to be similar to Hut V at Kilphedir. The house and its associated field systems are speculated to date from 130 BC, based on the Kilphedir chronology. This hut circle, located at NC 8681 2963, was excavated as part of Curle's investigations in 1910 (Curle, 1911; RCAMS, 1911). Some 'coarse' pot sherds were found, along with fragments of a lignite armlet. The armlet is possibly D-shaped in cross-section; ornaments of this type have been associated with Later Bronze Age settlements elsewhere in Britain (Annable & Simpson, 1968; Burgess, 1980).

The hut appears to have a rectilinear annex, which may be analogous to similar structures recorded from elsewhere in the Strath and from the excavations at Lairg (McCullagh &. Tipping, 1998). Curle's excavations also revealed a souterrain, but pressed for time, the excavation team could not explore it further (Curle, 1911). The house is situated in an "irregularly shaped" field system enclosed by stone and earthen banks. The 1993 survey also noted a lynchet associated with the house. A second house, NC 8669 2953, has an entranceway constructed partially of two very large boulders, as well as exhibiting extended and thickened wall terminals. Cultivation plots *ca.* 25.0m x 15.0m were recorded, defined by field walls, lynchets and clearance heaps. There is no additional information on the solitary hut circle located at NC 8701 2917. The RCAHMS records indicate the presence of a number of clearance heaps in the area, along with the aforementioned burial cairns.

Curle's investigations at Kinbrace are not the earliest example of antiquarian interest in the area. Reverend Sage, in the first Statistical Account of Scotland, noted that there were "...three subterraneaous [sic] passages, or tumuli... which it is said lead from one cairn under the bed of the River Helmsdale to another at the other side"; the Reverend when on to note that the general belief was that the builders of these passages retreated there with their cattle when under threat (*Stat. Acct.*, 1791-97). The area of Kinbrace has also been known by the Gaelic name of Suinachugh, and the Reverend Sage offers a possible etymology for the name. The Gaelic element, 'achugh' [a corrupted spelling of 'achadh'] means field, while the 'suin' element is probably Norse in origin and may be a possessive, translating into 'Suenus' Field'. Sage refers to the work of the Danish historian Torfaeus who wrote of a mid-12th century battle between one Suenus and an Aulver Roster in a cairn field. Incidentally, the hill immediately across the Helmsdale River is 'Cnoc Dail-Chairn', or Hill of the Valley of the Cairns. According to the *Orkneyingasaga*, Sweyn (Suenus), came to the Strath of Kildonan and attacked Oliver (Aulver) and Frakark. Oliver escaped, but his houses, some with his men inside, and Frakark ('the old hag'), were burnt.

defensive outerworks which are still well-preserved and consist of an inner ditch 8.0m wide and 2.0m deep, a rampart and slight outer ditch.

The area around Loch Ascaig, Borrobol and Ceannbhaid, is one of the earliest historically documented settled areas of the Strath of Kildonan. In the 13th century the land from Kildonan to Borrobol was 'set in feu' by the Abbott of Scone to Robert Little and his brother, David Sutherland. There are several townships and shielings located to the west of the loch, including Altanduin, Fernach and, closer to the study site, Ceannabhaid. Little is known about these townships, when they were occupied and by whom, but the form the bulk of the evidence for medieval and later settlement. Ceannabhaid, or 'Keenvad' as it appears, is listed on the Hearth Tax return of 1690 (RCAHMS, 1993).

Appendix III

Kildonan Lodge

The area around Kildonan Lodge reflects continuity of use extending at least as far back as the Neolithic. A long cairn is located within the Kildonan Lodge catchment, approximately 1km north east of the sampling site (Figure 5.4). No radiocarbon age estimations have been obtained for any of the cairns or chambered tombs in the Strath of Kildonan, but long cairns are generally ascribed to the period *ca.* 3700-2500 BC. Other structures represent settlement and use of the landscape from the second millennium BC up to the present day, including hut circles with field systems; a broch; farmsteads and a possible corn drying kiln (NC 914 182); a fang (*Sc. Ga.* A sheep pen) and a corrugated aluminium garage. Although the long cairn and the presence of several other types of Neolithic cairns attest to activity during this period, it represents the only evidence, apart from the Beaker fragment found in the clearance heap at Kilearnan Hill (McIntyre *et al.*, 1998).

Around 37 hut circles have been surveyed; many are damaged by later agricultural activity, with some overlain by field walls, others levelled by later cultivation (*eg.* NC 914 182). Several have has stones heaped into the interior (*eg.* NC 9165 1876) and one shows signs of having the entrance blocked with rubble, perhaps representing later attempts to clear land for cultivation of to improve grazing (*cf.* Edwards & Whittington, 1998) Three huts have rectilinear annexes giving them a 'keyhole' appearance (NC 914 184). A majority of the huts are set within well defined field systems with clearance heaps, lynchets and field walls inferred to be associated with the occupation of some of the huts (Group 3). There is however, considerable damage to prehistoric structures and features from other, later activities and the imposition of run rig.

In the main area of settlement, 17 hut circles are set within a field system of approximately 35 ha along the banks of the Allt a'choire mhoir (NC 914 182). The cluster of huts furthest south comprises 6 structures A-F (NC 914 183). Hut 'A'

described in the NMRS as being of 'massive construction', approximates to Mercer's Type 7 (1980; Table 3.1), and appears to be similar to Kilphedir Hut V (Fairhurst & Taylor, 1971), although with a smaller internal diameter, but exhibiting the characteristic thickened wall terminals, up to 4.0m. Hut 'B' also has thickened wall terminals, but is smaller again, with thinner walls. Of the remaining huts in the cluster, most have been severely damaged or destroyed by later cultivation. Hut 'E' is comparatively undamaged, with a later clearance heap within it, shows the remains of two rectangular annexes measuring 10.5 x 3.0m places on either side of the entrance.

One of the hut circles in the catchment has been excavated, but there is no published data available. A radiocarbon age estimation of 3200±50 BP (1543-1386 cal BC) from the excavation appeared in a recent publication (Cowley, 1998), however, the context of the sample was not clear, although it was implied that it derived from a primary context. The sample material appears to have originated from a section through the hut circle bank, and no mention of the sample material was made. Without more detailed information, this, unfortunately, adds little to the understanding of occupation histories of hut circles and settlements in the Strath of Kildonan. A kidney shaped burnt mound is located adjacent to the main area of settlement on boggy ground between the Allt a'choire mhoir and at the edge of run rig, which itself appears to have been imposed on an earlier field system. The burnt mound, which has been damaged and is partially collapsed is in close proximity to several huts and a homestead.

To the west of the larger area of settlement is a smaller field system of about 4 ha with cultivation pots of 20x30m surrounded by clearance heaps and lynchets. Nearby, to the NW are 5 more hut circles. These huts appear to be unremarkable for the most part in terms of morphological features. There are no formal fields, but because of the smooth even nature of the land surface around the huts, it was inferred that cultivation may have taken place (*cf*, Fairhurst & Taylor, 1971). Further west across the Allt na h-Airbhe is a simple, solitary hut circle with no evidence of formal field systems, although during survey it was noted that it was surrounded by several dry knolls which might have been suitable for cultivation (RCAHMS).

The cairnfield (NC 906 184) on the west bank of the All na h-Airbhe has been excavated (Russell-White, 1998). Initially, because of the lack of hut circles in the immediate area, it was hypothesised that it may represent a phase of Neolithic or Early Bronze Age activity. Several alleged anthropic features were noted during test pit sampling, including a hearth and post-holes. Charcoal was abundant in some of the pits, while others reflected elevated phosphate values. The only clear cut features were two parallel furrows, *ca.* 1-1.5m wide running E-W across the cairn field. These were cut into the buried soils and subsequently filled with peat Ard marks were found under a 30.0cm layer of peat, which gave a basal radiocarbon age estimation of AD 880-1040 TAQ for the ard marks. Age estimations for organic soils and peats extracted from underneath two of the clearance cairns were 810-390 cal BC and AD. 520-400

A broch (NC 9216 1887) is situated on the west bank of the Allt a'choire mhoir in state of near complete ruin, appearing mostly as a pile of stone rubble. During the survey, however, closer examination revealed that some of the original structure, either revetments or portions of wall, survived. The damage has been caused by the building of a forestry track and other undefined activity. The broch appears to have defensive outerworks, as the remains of a ditch and rampart were observed. Nearby is a cluster of 3 huts set with in a field system defined by clearance heaps, lynchets and the remains of field walls (NC 921 190). The entrance terminals to Hut 'B' are thickened and probably related to Mercer's Type 12 (Curle's 1b), similar to Huts I and II at Kilphedir. The huts have been filled with later clearance and spoils from road building. The relationship between the hut circles and the broch is unknown and none of the hut circles are known to be associated with souterrains.

Appendix IV

Laboratory Methods

Pollen Preparation and Analysis

Sampling and addition of marker spores

The outermost layer of material on the cores was cleaned away as it is a possible source of contamination introduced during coring. The sampling strategy employed a close interval analysis which is essential for resolving the often brief episodes of prehistoric human activity (Birks & Birks, 1980). Pollen analysis was carried out at 8.0, 4.0, 2.0 and as fine as 1.0 cm intervals to focus on later Holocene human impacts. Samples of 1 cm^3 measured by displacement in a solution of 10% Hydrocholoric acid (HCl 10%) in a 5.0 ml graduated cylinder. This process removes any traces of calcium carbonates ($CaCO_3$), however, since the sediments were highly organic peats with very little mineral matter, the addition of HCl 10% was primarily to enable the dissolution of marker spore tablets into the sample. Spore tablets of a known quantity (12, 540± 3%) of *Lycopodium clavatum* were added to the samples in HCl 10% to allow the estimation of pollen concentrations after Stockmarr (1971). The contents of the graduated cylinder were transferred to a polypropylene centrifuge tube and gently stirred with polytetraflourethylene (PFTE) rods. The sample was centrifuged at 3000 rpm for 5 minutes and the supernatant decanted. Centrifuging was done at this speed for all steps preceding acetolysis, where the speed was decreased to 2500 rpm to prevent crumpling of the pollen grains.

Disaggregation

A solution of 10% Sodium hydroxide (NaOH 10%) was added to the samples to extract the humic acids. The centrifuge tubes were placed in a boiling hot water bath for thirty minutes and stirred occasionally with the PFTE rods. After disaggregation, the fluid in the tubes appears dark brown as a result of the humic acids in solution. After being

centrifuged, the samples were washed repeatedly in distilled water and centrifuged until the supernatant was clear.

Removal of mineral matter and macrofossils

All samples were sieved through a 180 µm mesh to remove material larger than pollen grains followed by sieving through a 10 µm mesh. This last step is not strictly necessary for almost purely organic sediments such as these samples, but helps to produce a cleaner sample for counting.

Acetolysis

Acid hydrolysis was used to remove cellulose material. The acetolysis solution contains Sulphuric acid which is strongly hydrophobic, and the samples were dehydrated by adding 4ml of Acetic Acid, Glacial (>99%), stirred, centrifuged and decanted. A 9:1 acetolysis solution was prepared with 27 ml of Acetic Anhydride to 3 ml of Sulphuric acid (98%) in a polypropylene graduated cylinder. Using a pipette, 3.75 ml of solution was added to each centrifuge tube. These were placed into a hot water bath for 3-4 minutes and stirred periodically. The tubes were removed from the hot water bath, and 2 ml of Acetic acid, Glacial (>99%) was added to cool the samples before centrifuging at 2 500 rpm. To remove any residual solution, 4 ml of Acetic acid, Glacial (>99%) was added to the samples, which were stirred and centrifuged. The samples were then washed twice in distilled water to remove trace acids.

Silicone oil and mounting

Four milliliters of Tert-Butyl Alcohol (TBA) >99% was added to samples to dehydrate them before being placed in silicone oil mountant (Dow Corning 200/22, 500cs). After centrifuging and decanting, 2 ml of TBA was added to the tubes, which were agitated using a vortex mixer and the solution decanted into labeled 12x50 mm glass specimen tubes containing 0.2-0.3 ml of silicone oil. The samples were centrifuged, decanted and dried overnight in an oven or a Grant Heat Block at 45° C.

Peat Humification:

Humification: Sampling and Methods

Two centimetre thick contiguous samples were taken for the areas of particular interest; otherwise samples were contiguous four centimetre thick The samples were dried for several days in a drying cupboard. This slower method of drying prevents the samples from becoming too hard and makes them easier to process. Prior to grinding, samples were placed in an oven at 40° C for several hours to remove any residual moisture. The samples were ground with a mortar and pestle and 0.2 g was weighed into a 150ml conical flask. The remainder of the sample was reserved for determining the organic content of the peat. 100ml of freshly mixed 5% NaOH was added from a graduated cylinder. The time was noted as the conical flasks were placed on a hot plate for one hour.

After cooling, the solution was transferred from the flask to a 200 ml graduated cylinder which was topped up to the mark and shaken. Samples were filtered through a Whatman Qualitative 1 filter paper using a vacuum pump (McCulloch (*unpub*). 50 ml of solution was then diluted 3:1 (150ml of distilled water to 50ml of solution) in a 200ml flask and thoroughly mixed. Percentage light transmission through the resultant solution was measured on a colorimeter using 540 nm wavelength.

Loss-on-Ignition:

Ceramic crucibles were weighed, sediment samples were added and the crucible was weighed again. Samples were placed in a furnace for 4 hours at 550°C. After this they were transferred to a dessicator to cool before being re-weighed. A recent study of the comparability of LOI results (Heiri, *et al.*, 2001) suggest that this is the optimal time and temperature, as % dry weight loss becomes more dependent on other factors such as sample size at higher temperatures or for longer exposure times. Despite the desirability of having as a large a sample size as possible, the amount of material available is often limited by the number of different analyses being performed and the amount of sediment available.

Tephrpochronology:

Extracting tephra from sediments

Potential tephra horizons were detected using two means: the identification of significant numbers of shards (>25.0 μm) preserved during pollen preparations and by the acid digestion of 2 cm contiguous samples from the core. Visual identification of tephra shards can often be made owing to their distinctive morphology (Persson, 1971). The microtephra layers analysed were extracted from 1.0 cm sub-samples of peat using the acid digestion methods outlined by Dugmore, *et al.* (1992). Removing the organics using acid digestion does not affect the geochemistry of the shards and is recommended over alternative methods such as ashing, which may alter the potassium content (Dugmore, *et al.* 1992; Larsen, 1992). Although hydration of the surface of the shard can take place during the preparation process (Dugmore *et al.*, 1992), this is mitigated during the grinding and polishing process .

The peat samples were mixed with 50 ml of concentrated sulphuric acid (98%) in 200 ml conical flasks. The flasks were placed on a hot plate for 3-4 hours. At this stage, concentrated nitric acid was added using a Pasteur pipette one drop at a time to accelerate the removal of organic matter. When the contents of the flasks turned light yellow or clear in colour, the flasks were removed from hot plate and left to cool. The contents were diluted with distilled water, centrifuged and decanted several times to neutralise the solution as much as possible.

Mounting and polishing of tephra shards

Slides for mounting the tephra samples were roughened by grinding with 180μm grit and then cleaned in an ultrasonic bath submerged in a solution of petroleum ether. The process of roughening the slide surface improves the sample's adherence. The tephra sample was transferred using a Pasteur pipette to the roughened slide surface and dried on a hot plate at 70°C. After the sample was thoroughly dried, araldite was added to adhere it to the slide. After the sample had hardened, the surface was ground to a thickness of *c.*75μm using a 600μm grit for the initial grinding, followed by 200 μm. The samples

were cleaned in the ultrasonic bath with petroleum ether, then polished by hand using 6μm and 1μm diamond paste, respectively. The polishing removes scratches made during the grinding and permits better focusing of the electron beam during analysis.

Geochemical identification of tephras using an electron microprobe (EMP)

The Cambridge Instruments electron microprobe of the Department of Geology, University of Edinburgh was used to analyse individual glass shards for relative percentage weights of selected major elements. After carbon coating, the tephras were analysed using a standard wavelength dispersive (WDS) technique, an accelerating voltage of 20kV and a beam current of 15nA. Nine major elements were analysed using two spectrometers: silica (Si), titanium (Ti), aluminium (Al), iron (Fe), manganese (Mn), magnesium (Mg), calcium (Ca), sodium (Na) and Potassium (K). All elements were subjected to a counting time of ten seconds.

Alkalis such as sodium and potassium are unstable when analysed by EMP. The mobilisation of alkalis will occur for as long as the sample is exposed to the electron beam and elements that are subsequently analysed may be over-represented (Hill & Hunt, 1993). In order to mitigate the problem, sodium is analysed during the first and second counting, to assess the degree of mobility; the beam is slightly defocused from the usual 1 μm to 5 μm (Hill, *pers comm*). The electron microprobe (EMP) is calibrated using a set of known standards which are a combination of pure metals and silica compounds. In order to detect unforeseen irregularities developing in the operating parameters of the EMP, an andradite standard was periodically analysed during each session.

Appendix V

Tephra: Geochemical Data

Kildonan Lodge

Katla Tephra									
SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	K2O	Total
47.26	4.94	12.76	12.81	0.21	5.49	11.24	2.79	0.59	98.09
47.22	5.08	12.60	14.92	0.24	4.77	10.37	2.89	0.86	98.95
46.68	4.47	12.19	13.68	0.32	4.76	9.13	3.16	0.75	95.14
46.63	5.05	12.11	15.10	0.26	5.13	9.92	2.81	0.65	97.66
46.54	4.38	12.38	14.47	0.30	4.98	9.65	3.18	0.73	96.61
46.32	4.79	12.45	16.28	0.32	4.71	9.78	2.61	0.68	97.94
46.31	4.65	12.29	15.62	0.26	4.88	9.63	2.97	0.65	97.26
45.38	5.02	12.32	15.95	0.24	4.84	9.61	2.89	0.73	96.98
44.91	0.75	10.84	16.16	0.21	10.42	11.07	1.03	0.33	95.72

Hekla 4 tephra									
SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	K2O	Total
73.38	0.11	12.64	2.04	0.04	0.02	1.28	4.05	3.07	96.63
73.16	0.15	12.76	1.90	0.05	0.04	1.25	4.32	2.94	96.57
72.91	0.10	12.06	2.12	0.06	0.05	1.38	4.29	3.00	95.97
72.83	0.06	12.59	1.78	0.09	0.04	1.27	4.19	2.72	95.57
72.64	1.06	12.48	3.84	0.08	0.42	2.37	3.44	1.94	98.27
72.50	0.14	12.84	1.93	0.09	0.05	1.39	4.11	2.87	95.92
72.45	0.08	12.61	1.86	0.11	0.06	1.36	3.43	2.88	94.84
72.07	0.11	12.70	1.78	0.10	0.06	1.18	4.18	2.81	94.99
72.06	0.50	12.38	3.76	0.11	0.45	2.35	2.88	2.03	96.52
71.96	0.13	12.59	1.93	0.12	0.05	1.37	4.02	2.78	94.95
71.49	0.14	12.55	1.81	0.11	0.01	1.25	3.83	2.64	93.83
71.32	0.21	13.64	3.17	0.14	0.02	1.89	4.11	2.55	97.05
71.17	0.35	12.70	2.39	0.14	0.32	1.72	3.81	2.83	95.43
71.14	0.18	13.78	3.23	0.14	0.04	1.99	4.05	2.49	97.04
70.90	0.27	13.54	3.09	0.17	0.07	1.87	4.30	2.52	96.73
70.81	0.21	13.81	3.94	0.23	0.05	2.26	3.23	2.45	96.99
70.19	0.16	13.43	3.11	0.13	0.04	1.93	3.81	2.59	95.39
69.91	0.17	13.14	2.78	0.08	0.06	1.64	4.34	2.54	94.66
69.64	0.23	13.99	4.26	0.19	0.11	2.45	3.79	2.28	96.94
68.71	0.81	12.53	4.54	0.15	0.61	2.63	3.44	1.79	95.21
68.61	0.23	13.40	3.91	0.19	0.07	2.41	3.03	2.43	94.28
68.31	0.27	13.74	4.47	0.17	0.10	2.53	3.69	2.24	95.52
68.21	0.73	12.60	4.62	0.15	0.63	2.84	3.53	1.88	95.19
67.77	0.30	13.96	5.18	0.21	0.12	2.89	4.45	2.25	97.13
67.76	0.31	13.87	4.45	0.19	0.09	2.70	2.91	2.24	94.52

66.88	0.35	13.79	5.46	0.18	0.15	3.03	4.18	2.11	96.13
66.62	0.30	13.92	4.94	0.19	0.12	2.80	3.86	2.17	94.92
66.58	0.48	14.24	6.96	0.30	0.28	3.56	3.98	2.09	98.47
66.25	0.37	13.76	4.95	0.18	0.12	2.73	3.31	2.23	93.90
66.03	0.44	14.04	7.13	0.24	0.30	3.46	3.62	1.97	97.23
65.68	0.41	14.00	6.63	0.32	0.27	3.74	3.99	2.03	97.07
63.10	0.67	14.19	8.62	0.29	0.61	4.23	4.13	1.73	97.57
62.50	0.73	14.39	9.01	0.26	0.67	4.10	3.76	1.82	97.24
62.25	0.62	14.36	9.01	0.32	0.55	4.38	3.94	1.86	97.29

Glen Garry tephra									
SiO2	**TiO2**	**Al2O3**	**FeO**	**MnO**	**MgO**	**CaO**	**Na2O**	**K2O**	**Total**
73.68	0.52	12.57	3.82	0.07	0.40	2.34	3.14	1.99	98.53
73.65	0.15	12.99	1.86	0.06	0.03	1.27	4.08	2.81	96.90
73.64	0.55	12.59	3.92	0.14	0.41	2.32	3.51	1.93	99.01
73.56	0.45	12.70	3.80	0.13	0.46	2.23	3.24	2.00	98.57
73.30	0.57	12.53	4.00	0.15	0.39	2.27	3.66	2.02	98.89
73.29	0.06	13.08	1.53	0.08	0.05	0.74	3.78	4.97	97.58
73.18	0.54	12.54	4.02	0.14	0.42	2.24	3.60	1.99	98.67
73.14	0.47	12.47	3.97	0.11	0.45	2.40	3.50	2.23	98.74
73.09	0.50	12.33	3.70	0.07	0.45	2.11	3.42	2.03	97.70
72.92	0.52	12.44	3.70	0.11	0.44	2.26	3.58	2.11	98.08
72.85	0.51	12.51	3.89	0.09	0.44	2.26	3.57	1.94	98.06
72.81	0.46	12.54	3.73	0.08	0.46	2.16	3.47	2.02	97.73
72.80	0.47	12.30	3.78	0.10	0.40	2.21	3.38	2.09	97.53
72.54	0.64	12.57	4.10	0.12	0.56	2.64	3.44	1.90	98.51
72.52	0.53	12.53	4.10	0.15	0.44	2.42	3.66	1.86	98.21
72.46	0.70	12.73	4.44	0.13	0.54	2.65	3.26	2.02	98.93
72.08	0.49	12.24	3.73	0.10	0.43	2.17	3.54	2.07	96.85
71.98	0.40	11.63	3.96	0.10	0.41	2.27	3.62	1.79	96.16
71.69	0.54	12.34	3.86	0.08	0.40	2.09	3.26	2.06	96.32
71.47	0.53	12.40	3.87	0.09	0.41	2.41	3.34	2.01	96.53
71.46	0.66	12.62	4.52	0.17	0.51	2.48	3.37	2.08	97.87
71.45	0.68	12.67	4.64	0.10	0.57	2.87	2.77	2.03	97.78
70.83	0.61	12.88	4.55	0.15	0.59	2.66	3.53	1.93	97.73
70.58	0.70	12.63	4.74	0.11	0.69	3.00	3.51	1.80	97.76
70.44	0.70	13.00	4.90	0.17	0.62	2.86	3.01	1.79	97.49
70.29	0.73	13.04	4.60	0.11	0.64	2.85	3.52	1.78	97.56
70.06	0.57	12.38	3.81	0.10	0.46	2.03	3.65	2.09	95.15
69.44	0.76	13.10	5.27	0.10	0.85	3.41	3.50	1.64	98.07
69.29	0.28	13.81	4.45	0.20	0.08	2.56	4.03	2.34	97.04
69.27	0.86	13.07	6.09	0.23	0.92	3.64	3.24	1.75	99.07
68.69	0.94	12.97	5.37	0.12	0.90	3.46	3.30	1.72	97.47
68.00	0.90	13.12	5.67	0.13	0.89	3.36	2.96	1.80	96.83
67.93	1.00	13.19	5.92	0.12	1.04	3.74	3.08	1.62	97.64
67.25	1.06	13.05	6.49	0.19	1.19	4.18	3.42	1.54	98.37
66.38	1.06	13.05	6.76	0.15	1.27	4.39	3.23	1.50	97.79

65.55	0.83	12.54	5.38	0.16	0.84	3.35	2.90	1.54	93.09
65.28	1.12	13.09	6.85	0.19	1.51	4.39	3.58	1.49	97.50
62.75	1.20	13.13	7.07	0.19	1.83	4.87	3.50	1.27	95.81
62.57	1.37	13.60	7.90	0.18	1.90	5.32	3.53	1.37	97.74
61.93	1.32	13.29	7.85	0.41	1.94	5.29	3.58	1.25	96.86
61.76	1.14	12.80	7.47	0.24	2.48	5.76	3.48	1.25	96.38
61.44	1.32	13.34	8.14	0.21	1.94	5.25	3.65	1.31	96.60
61.18	1.24	13.29	7.60	0.16	2.59	5.96	3.36	1.13	96.51
60.76	1.46	13.29	8.27	0.23	2.37	5.56	3.24	1.15	96.33

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Hekla 4 tephra									
SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO3	NaO2	K2O	Total
74.25	0.13	12.93	1.95	0.09	0.02	1.31	4.25	2.94	97.86
73.25	0.13	12.70	1.86	0.04	0.02	1.35	4.18	2.72	96.23
73.04	0.08	12.47	2.02	0.08	0.03	1.32	4.21	2.72	96.00
72.85	0.12	12.67	1.94	0.07	0.04	1.37	4.33	2.79	96.18
72.77	0.14	12.47	1.90	0.04	0.05	1.30	4.53	2.78	95.97
72.46	0.11	12.66	1.76	0.08	0.06	1.38	4.34	2.72	95.57
72.25	0.16	12.54	1.95	0.04	0.04	1.40	4.34	2.87	95.59
72.06	0.14	12.32	1.82	0.33	0.07	1.39	3.84	2.77	94.74
70.27	0.28	13.58	3.72	0.09	0.08	2.18	4.42	2.49	97.11
70.03	0.21	13.16	2.53	0.13	0.04	1.90	4.02	2.64	94.67
69.00	0.37	13.71	3.91	0.18	0.09	2.44	4.61	2.45	96.81
68.75	0.28	13.09	4.06	0.14	0.12	2.54	4.46	2.40	95.84
68.12	0.29	13.86	4.65	0.24	0.12	2.53	4.33	2.04	96.19
62.57	0.69	14.46	8.45	0.32	0.71	4.27	4.32	1.77	97.55
68.75	0.28	13.09	4.06	0.14	0.12	2.54	4.46	2.40	95.84
69.00	0.37	13.76	3.91	0.18	0.09	2.44	4.61	2.45	96.81
72.25	0.16	12.54	1.95	0.04	0.04	1.40	4.34	2.87	95.59
72.85	0.12	12.67	1.94	0.07	0.04	1.37	4.33	2.79	96.18
62.57	0.69	14.46	8.45	0.32	0.71	4.27	4.32	1.77	97.56
69.61	0.16	12.06	1.96	0.07	0.02	1.24	3.43	2.57	91.12
70.27	0.28	13.58	3.72	0.09	0.08	2.18	4.42	2.49	97.11
73.25	0.13	12.70	1.86	0.04	0.02	1.35	4.18	2.72	96.25
72.06	0.14	12.32	1.82	0.33	0.07	1.39	3.84	2.77	94.74
55.16	0.08	9.60	1.65	0.00	0.01	0.97	2.92	2.23	72.62
74.25	0.13	12.93	1.95	0.09	0.02	1.31	4.25	2.94	97.87
73.04	0.08	12.47	2.02	0.08	0.03	1.32	4.21	2.72	95.97
70.03	0.21	13.16	2.53	0.13	0.04	1.90	4.02	2.64	94.66
72.77	0.14	12.47	1.90	0.04	0.05	1.30	4.53	2.78	95.98
72.46	0.11	12.66	1.76	0.08	0.06	1.38	4.34	2.72	95.57
68.12	0.29	13.86	4.65	0.24	0.12	2.53	4.33	2.04	96.18
69.38	0.33	13.90	4.60	0.17	0.09	2.79	3.87	2.33	97.46
74.25	0.13	12.93	1.95	0.09	0.02	1.31	4.25	2.94	97.86
73.25	0.13	12.70	1.86	0.04	0.02	1.35	4.18	2.72	96.23
73.04	0.08	12.47	2.02	0.08	0.03	1.32	4.21	2.72	96.00

72.85	0.12	12.67	1.94	0.07	0.04	1.37	4.33	2.79	96.18
72.77	0.14	12.47	1.90	0.04	0.05	1.30	4.53	2.78	95.97
72.46	0.11	12.66	1.76	0.08	0.06	1.38	4.34	2.72	95.57
72.25	0.16	12.54	1.95	0.04	0.04	1.40	4.34	2.87	95.59
72.06	0.14	12.32	1.82	0.33	0.07	1.39	3.84	2.77	94.74
70.27	0.28	13.58	3.72	0.09	0.08	2.18	4.42	2.49	97.11
70.03	0.21	13.16	2.53	0.13	0.04	1.90	4.02	2.64	94.67
69.00	0.37	13.71	3.91	0.18	0.09	2.44	4.61	2.45	96.81
68.75	0.28	13.09	4.06	0.14	0.12	2.54	4.46	2.40	95.84
68.12	0.29	13.86	4.65	0.24	0.12	2.53	4.33	2.04	96.19
62.57	0.69	14.46	8.45	0.32	0.71	4.27	4.32	1.77	97.55

Glen Garry tephra									
SiO2	**TiO2**	**Al2O3**	**FeO**	**MnO**	**MgO**	**CaO3**	**NaO2**	**K2O**	**Total**
72.94	0.59	12.57	3.82	0.08	0.38	2.26	3.86	2.05	98.55
73.04	0.51	12.42	3.66	0.12	0.44	2.42	3.76	2.03	98.39
58.09	1.27	13.14	8.31	0.20	4.04	7.50	3.43	1.02	97.00
71.60	0.10	12.63	1.88	0.00	0.04	1.31	4.02	2.74	94.32
69.41	0.75	12.71	4.57	0.12	0.68	2.91	3.63	1.82	96.59
70.45	0.47	11.69	3.52	0.07	0.47	2.28	3.02	2.01	93.96
69.30	0.65	12.76	5.10	0.12	0.72	3.10	3.39	1.70	96.85
69.75	0.67	12.77	4.63	0.15	0.70	3.16	3.30	1.72	96.84
69.82	0.66	12.71	4.64	0.16	0.72	3.12	3.49	1.89	97.22
66.94	1.02	12.94	6.01	0.17	0.99	3.71	3.59	1.48	96.10
72.94	0.59	12.57	3.82	0.08	0.38	2.26	3.86	2.05	98.55
73.04	0.51	12.42	3.66	0.12	0.44	2.42	3.76	2.03	98.40
72.25	0.58	12.32	3.76	0.05	0.47	2.54	3.35	1.96	97.28
73.10	0.52	12.42	3.86	0.08	0.43	2.26	3.52	2.00	98.19
58.09	1.27	13.14	8.31	0.20	4.04	7.50	3.43	1.02	97.00
71.60	0.10	12.63	1.88	0.00	0.03	1.31	4.02	2.74	94.31
69.41	0.75	12.71	4.57	0.12	0.68	2.91	3.63	1.82	96.60
70.45	0.47	11.69	3.52	0.07	0.47	2.28	3.02	2.01	93.98
69.30	0.65	12.76	5.10	0.12	0.72	3.10	3.39	1.70	96.84
69.75	0.67	12.77	4.63	0.15	0.70	3.16	3.30	1.72	96.85
69.82	0.66	12.71	4.64	0.16	0.72	3.12	3.49	1.89	97.21
66.19	1.02	12.94	6.01	0.17	0.99	3.71	3.59	1.48	96.10
67.47	1.05	12.84	6.05	0.13	1.07	4.10	3.58	1.65	97.94
72.68	0.55	12.41	3.67	0.09	0.38	2.21	3.35	2.18	97.52
73.77	0.49	12.58	3.70	0.06	0.42	2.24	3.55	2.19	99.00
73.82	0.52	12.44	3.78	0.08	0.43	2.38	3.54	2.01	99.00
73.24	0.55	12.56	3.69	0.08	0.38	2.35	3.54	2.02	98.41
73.94	0.57	12.51	3.75	0.09	0.42	2.20	3.62	2.04	99.14
72.24	0.75	12.84	4.70	0.12	0.61	2.73	3.79	1.91	99.69
72.58	0.64	12.63	4.56	0.06	0.51	2.51	3.76	1.90	99.15
72.66	0.51	12.48	3.64	0.11	0.39	2.36	3.60	2.06	97.81
73.04	0.48	12.43	3.78	0.08	0.45	2.37	2.97	1.92	97.52

70.74	0.89	12.66	6.34	0.06	0.76	3.17	3.58	1.86	98.60
69.43	0.74	12.89	5.00	0.15	0.69	3.34	3.46	1.81	97.51
69.60	0.43	12.02	3.71	0.11	0.46	2.26	3.19	2.00	93.78
72.94	0.58	12.31	3.86	0.06	0.40	2.10	3.33	2.09	97.67
65.83	0.75	12.18	4.89	0.10	0.67	2.66	3.18	1.65	91.91
56.43	1.29	13.15	8.83	0.18	4.40	8.34	3.03	0.81	96.46
72.91	0.57	12.25	3.62	0.07	0.40	2.12	3.38	1.96	97.28
73.53	0.49	12.58	3.76	0.06	0.43	2.17	3.46	1.96	98.44

Kinbrace Hill

Lairg B tephra									
SiO_2	TiO_2	Al_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	Total
70.99	0.33	14.18	2.21	0.04	0.17	0.76	2.72	4.62	96.02
70.49	0.24	13.98	2.25	0.09	0.16	0.76	2.89	4.82	95.68
66.67	0	0	2.2	0	0	0.69	4.37	4.74	78.67
70.47	0.22	13.88	2.17	0.02	0.16	0.77	3.42	4.81	95.92
69.78	0.19	13.66	2.25	0.05	0.15	0.73	4.81	4.33	95.95
70.38	0.27	13.69	2.09	0	0.13	0.7	4.54	4.71	96.51
70.46	0.22	13.89	2.24	0.04	0.13	0.64	3.09	4.85	95.56
70.07	0.2	13.68	2.1	0.08	0.13	0.65	4.18	4.89	95.98
70.54	0.21	13.83	2.26	0.03	0.12	0.6	4.01	4.84	96.44
70.26	0.27	14.06	2.36	0.03	0.2	0.82	5.01	4.44	97.45
69.02	0.22	13.49	2.25	0.01	0.14	0.76	3.37	4.95	94.21
68.97	0.35	14.36	2.54	0.04	0.26	1.08	4.77	4.28	96.65
70.81	0.22	13.83	2.09	0.02	0.13	0.7	3.63	4.94	96.37
66.11	0.16	13.08	2.09	0.03	0.15	0.72	3.64	4.64	90.62
68.31	0.26	13.54	2.21	0	0.16	0.72	4.08	4.5	93.78
70.44	0.18	13.71	2.21	0.07	0.13	0.67	3.22	4.73	95.36
69.34	0.25	13.79	2.17	0.03	0.14	0.74	3.53	4.87	94.86
68.4	0.33	14.05	2.65	0	0.25	1.02	4.06	4.24	95
69.94	0.19	13.71	2.27	0.07	0.17	0.79	4.6	4.39	96.13
70.48	0.26	13.9	2.24	0.08	0.14	0.76	3.38	4.83	96.07
67.39	0.22	12.9	2.12	0.04	0.17	0.65	4.03	4.46	91.98
69.39	0.29	13.69	2.45	0.05	0.16	0.72	4.69	4.33	95.77
70.06	0.22	13.8	2.13	0.05	0.13	0.72	4.19	4.72	96.02
69.77	0.24	14.06	2.22	0.09	0.2	0.86	4.81	4.44	96.69
68.73	0.28	13.82	2.22	0.04	0.16	0.91	5.11	4.51	95.78
68.99	0.18	13.44	2.08	0.03	0.17	0.71	3.26	4.53	93.39
70.8	0.24	13.66	2.12	0.05	0.16	0.72	3.62	5.09	96.46
68.61	0.34	14.17	2.55	0.04	0.26	1	4.13	4.5	95.6
71.39	0.07	12.29	1.9	0.03	0.06	1.28	3.75	2.6	93.37
68.88	0.32	13.85	4.5	0.13	0.07	2.58	4.52	2.3	97.15
68.84	0.33	13.95	4.62	0.16	0.09	2.63	4.33	2.22	97.17

Hekla 4									
SiO_2	TiO_2	Al_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	Total
60.4	0.68	13.62	8.99	0.27	0.54	4.19	4.04	1.67	94.90
70.13	0.13	12.35	1.96	0.09	0.02	1.21	3.25	2.48	95.62
71.83	0.14	12.55	1.91	0.06	0	1.33	4.22	2.73	94.77
70.67	0.17	12.27	1.9	0.08	0.02	1.17	3.38	2.48	95.14
70.85	0.24	13.58	3.5	0.15	0.04	2.02	4.27	2.28	96.4
67.66	0.2	12.84	3.25	0.13	0.06	1.92	3.82	2.47	94.45
66.57	0.4	13.93	4.97	0.2	0.17	3.04	3.79	1.97	95.04
67.41	0.35	14.04	4.86	0.17	0.16	2.9	4.51	2.34	93.74
64.42	0.35	13.36	5.26	0.12	0.17	2.55	4.12	2.1	95.22
67.07	0.24	14.05	5.25	0.19	0.13	2.88	4.28	2.12	96.21
61.3	0.71	13.96	9.49	0.27	0.68	4.41	3.81	1.63	96.26
73.94	0.12	12.4	1.64	0.08	0.04	1.29	3.46	2.79	95.76
71.69	0.09	12.03	1.63	0.04	0.06	1.27	2.2	2.71	95.21
70.93	0.23	13.82	3.51	0.12	0.04	2.07	4.25	2.52	97.49
62.33	0.67	14.03	8.01	0.27	0.52	4.04	3.8	1.87	95.54
69.19	0.25	13.42	3.55	0.15	0.05	2.09	3.87	2.59	95.16
66.03	0.3	13.15	3.52	0.06	0.04	2.2	3.92	2.19	94.14
70.13	0.26	13.81	3.85	0.19	0.06	2.33	4.24	2.45	97.32
70.04	0.22	13.53	3.64	0.13	0.07	2.24	3.88	2.31	96.06
72.87	0.09	12.55	1.97	0.09	0.02	1.42	3.43	2.95	95.39
70.58	0.08	12.21	1.65	0.01	0.02	1.34	3.27	2.78	91.94
71.01	0.12	11.67	2.04	0.04	0.05	1.35	2.69	2.63	95.6
74.04	0.14	12.86	1.93	0.06	0.03	1.28	4.08	2.82	97.24
68.16	0.3	13.58	4.36	0.14	0.09	2.26	3.11	2.15	95.21
69.22	0.29	13.77	4.2	0.15	0.07	2.4	4.01	2.27	96.38
69.85	0.27	13.64	3.79	0.13	0.08	2.38	4.31	2.36	97.11
66.28	0.42	13.97	6.22	0.14	0.15	3.22	3.89	2.05	96.34
66.43	0.32	13.16	4.41	0.13	0.23	2.34	3.89	2.12	93.03
71.98	0.12	12.41	1.8	0.08	0.01	1.21	3.86	2.77	94.24
69	0.23	13.26	3.16	0.12	0.05	1.83	3.67	2.27	93.59
71.74	0.2	13.82	3.14	0.11	0.05	1.82	4.29	2.45	97.62
71.42	0.19	13.53	2.98	0.09	0.03	1.93	4.47	2.51	97.15
71.59	0.19	13.58	2.87	0.08	0	1.81	4.33	2.58	97.03
69.37	0.19	13.23	2.85	0.07	0.03	1.77	3.62	2.62	95.22
71.28	0.2	13.72	3.42	0.13	0.04	2.17	4.35	2.51	97.82
70.22	0.19	13.72	3.37	0.11	0.03	1.95	4.03	2.46	96.08
70.03	0.26	13.61	3.86	0.12	0.06	2.3	4.4	2.52	97.16
73.4	0.12	12.94	1.94	0.06	0.02	1.21	4.08	2.82	96.59
69.79	0.29	13.68	4.05	0.14	0.05	2.22	4.17	2.35	96.74

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