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The landscape context of the Antonine Wall: a review of the literature

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ABSTRACT

The landscape, environmental and land use changes before, during and after Antonine occupation are examined for the region of central Scotland between the Southern Uplands and the Grampian Highlands, principally from the published literature. The purpose is to synthesize and make available a range of new palaeoenvironmental data, to evaluate critically these new data-sets, to search for significant shifts in landscape or land use and to characterize their timings and effects, thus placing the Antonine occupation in a coherent landscape context. It is established that economic expansion in the region occurred in the later Iron Age, demonstrably before Roman military occupation. This expansion developed from Bronze Age and earlier Iron Age small-scale farms and gathered pace in the last cal 200–300 years BC*, for crop growing as well as pasture, and was continued rather than intensified in the first two centuries cal* AD*. It is difficult to see differences in this economic expansion north and south of the Antonine Wall itself, or east and west of the Forth–Clyde isthmus, but it is tentatively suggested that in the foothills of the Southern Uplands the Romans entered a landscape already decaying. Roman influence is perhaps recognizable at some localities in a reduction of cereal production and the expansion of grazed pasture, assumed to represent a restructuring of the native economy to support a new market. It is presumed that imports of foodstuffs continued to be important to Roman forces during Antonine occupation, although possible reconstructions of the sediments in the Forth and Clyde estuaries suggest these may not have provided ideal harbours. There is little evidence that this increased pastoral economy imposed stresses on soils or plant communities, and the market seems to have been readily supplied within the agricultural capacity of the landscape. Nevertheless, the native economy was probably artificially buoyed by the Roman presence, and withdrawal eventually led to what is best described as an agricutural recession, not population collapse.*

LANDFORMS

This review defines central Scotland as broadly that band of country between the Southern Uplands Fault and the Highland Boundary Fault (illus 1). This is a geological definition. It is a moot point whether it had relevance to people in the second century AD, our temporal focus, but here geological formations have pronounced topographic expression (Whittow 1977) and at least subconsciously these would have meant much at this time (Hanson 1997).

South of the Southern Uplands Fault, the rounded hills of soft Palaeozoic mudstones merge with the northern Pennine landscape of Hadrian's Wall. Descent north from the Moorfoot Hills along Dere Street is a major fall of 250m to the Forth Coastal Plain. On the west the change is less dramatic, the River Clyde providing a more gentle fall. Central Scotland itself is not

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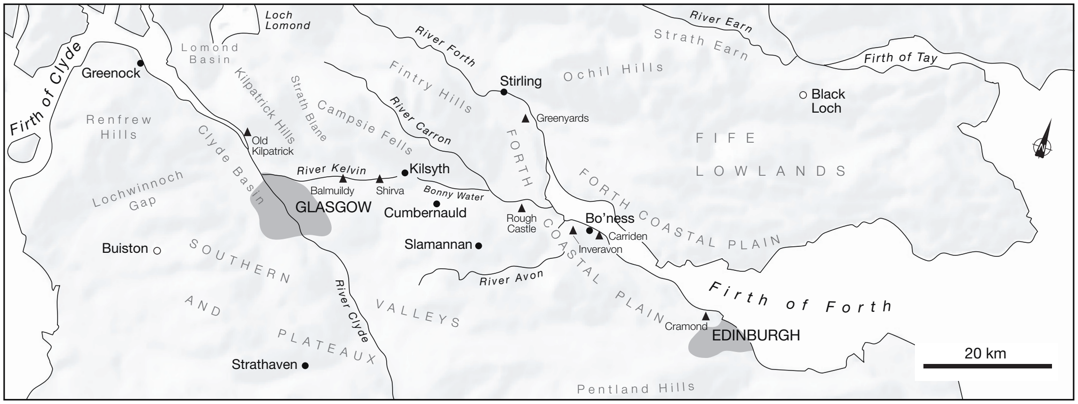


ILLUS 1 The region of central Scotland considered in this review, outlining the major landforms defined and the present day cities and towns mentioned in the text, and showing the positions of sediment stratigraphies and archaeological sites away from the Wall used in the interpretations of coastal and geomorphic change

a uniform stretch of country, and is not even primarily low-lying (Whittow 1977). We define seven landforms, here emphasized in italics (illus 1). The volcanic ridge of the *Pentland Hills* rises to 600m OD, projecting through the low-lying and easily eroded Carboniferous sediments of the *Forth Coastal Plain* almost to the coast (we have limited our review to the region west of this ridge). The Pentlands also extend west into the incised *Southern Valleys and Plateaux* of the upper Clyde and its tributaries, and these plateau surfaces continue west to Strathaven and to the coast near Greenock, the western edge of our region, pierced only by the upper Clyde and the Lochwinnoch Gap. Between Glasgow and Edinburgh and extending north to Slamannan and Cumbernauld, the till-covered Carboniferous Coal Measures also form a broad plateau surface of cold clay soil and shallow peat between 250 and 300m OD, unnoticed today but sufficiently climatically marginal to have inhibited settlement until the beginning of the industrial revolution (Whyte 1979).

The *Midland Valley* is here limited to the Clyde basin and the glacially breached through-valley now drained westward to the Clyde from Kilsyth by the River Kelvin and eastward from Kilsyth by the Bonny Water and eventually the River Carron; the watershed is at less than 50m OD. Punctuating this valley on its south side are the crests of sharply etched east/west oriented doleritic dykes and sills providing the route of the Antonine Wall in its central section. The Rivers Carron and Avon flow across the Forth Coastal Plain on a low platform of mid-Holocene estuarine sediments, the 'carse' clays.

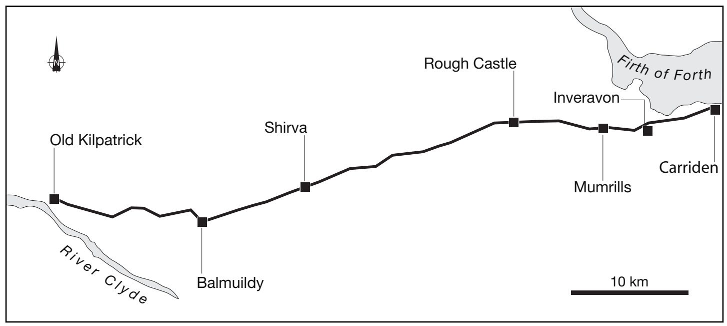
Immediately north of the River Kelvin a huge wall of Carboniferous lavas rises in the fault-controlled scarp of the *Kilpatrick and Campsie Fells*, an extension of the Renfrew Hills south of the Clyde, intersected only by Strath Blane and the drumlinized lowlands of the *Lomond Basin*. North of the Campsies and east of the Lomond Basin is the Carron Valley, and north of this the Carboniferous lavas of the Fintry, Gargunnock, Touch and Ochil Hills. East of these are the *Fife Lowlands*, with the comparable Strath Earn, flowing to the River Tay.

THE SEA

The Wall terminates at both ends in the estuaries of the Clyde and the Forth (illus 1). Both have changed beyond all recognition since the second century AD. In particular, relative sea level has changed. This was highest in most parts of Scotland in the middle of the Holocene, before *c* cal 4500 BC (Smith et al 2000; Shennan & Horton 2002), declining in altitude away from the centre of uplift in western Scotland, and geomorphically marked either by erosional shorelines or by flat-lying surfaces of sediments mostly representing former estuarine mudflats called 'carse' clay, the Main Post-glacial Shoreline (Smith et al 2000). In the middle Forth estuary, the highest Main Post-glacial Shoreline is around 9–12m OD. In the Clyde estuary, near Old Kilpatrick, it is 13–14m OD (Rose 2003).

Recently, Smith et al (2000) have recognized one later regionally significant Holocene shoreline that may represent a rise in relative sea level, perhaps to altitudes close to that of the Main Post-glacial Shoreline, the Blairdrummond Shoreline. One interpretation of its chronology is for this high relative sea level to have been maintained to the BC/AD boundary (Smith et al 2000). Such a high sea level might have made the Firths wider and more forbidding obstacles. Nevertheless, radiocarbon controls on this event in central Scotland suggest that sea level had fallen by 1500 cal BC (Boyd 1986), but may have been interrupted, rather than a smooth transition, because a number of lower shorelines are recorded (Smith 1968; Rose 2003). An absence of securely radiocarbon-dated controls on these later events makes us reliant on generalized sea level curves (eg Shennan & Horton 2002) which indicate sea levels of around 3m OD in the central Forth estuary 2000 cal years ago; geological data are too few to estimate these for the Clyde estuary. Archaeological data might be used to test these reconstructions (illus 2): construction of the Wall and fortlet at Inveravon (Dunwell & Ralston 1995) on a 'carse' surface at *c* 5m OD may indicate that mean sea level here was below this in the second century AD. It would be interesting to know whether spring high tides impacted on the defences at Inveravon. The recently surveyed Clyde crannogs (Hale 2000) may also, when estimates of contemporaneous sea levels are available, refine our understanding.

One effect of a sea level above present may have been to affect groundwater supplies. Excavations at Cramond (illus 1) produced insect remains from a well some 3m deep, and currently 2m below the water table, that indicated the water in the well to have been 'somewhat saline' and not drinkable (Raisen 2003, 137); the altitude of this feature is unfortunately not published. The setting of the Cramond 'lioness' within present-day intertidal sediments (Hunter & Collard 1997) needs to be explored to define contemporary environments and water depth.



ILLUS 2 Archaeological sequences on and close to the Wall used in the interpretations of coastal and geomorphic change

Estuaries are rendered less forbidding obstacles by the accumulation of fine-grained sediments in mudflats and sandbanks. Always notorious for its shallowness, the natural course of the Clyde downstream of Old Kilpatrick (illus 2) featured extensive shoals and sandbanks (Riddell 1979). In AD 1755, these restricted water depth at low water to less than a metre. Although precise environmental reconstructions have yet to be made for the later Iron Age or Roman Iron Age marine crannogs in the Clyde estuary (Hale 2000), it seems most likely that mudflats and sandbanks were extensive during the Antonine occupation. In the Forth estuary, more assured reconstructions show that laterally extensive intertidal estuarine sediments, deposited beneath negligible water depths, extended from the cliffs at Falkirk out towards the present Kincardine Bridge (Robinson 1993; Paul et al 1995). An elevated sea level in the second century AD would not necessarily have increased the depth of flow because active sandbank and mudflat surfaces will also have risen. Such extensive muds were at least potentially fordable (Riddell 1979), making the firths rather permeable barriers. These shallows and shoals probably isolated the west end of the Wall at Old Kilpatrick from sizeable supply ships. Mudflats in the Forth estuary, filling the embayment west of Bo'ness, would have had comparable impacts and presumably necessitated the development of docking facilities further downstream. Cramond has often been seen as providing these (Shotter 1996; Hunter & Collard 1997) yet there is currently no archaeological evidence for a port here (Holmes 2003); perhaps ships of deep draught anchored in mid-estuary. A more typical native craft of the shallows would have been the logboat (Mowat 1996; Hale 2003).

On the Clyde, Old Kilpatrick fort probably stood at the water's edge on a raised beach carved during deglaciation (Rose 1975). On the Forth estuary, the Wall east of Inveravon has evidence that the coast has retreated since Roman occupation. The fort at Carriden stands on a high cliff but the only limited evidence for the seaward defensive ditches (Bailey 1997) suggests that this cliff has retreated by an unknown distance since the second century AD: some of the most seaward fields of the system east of the fort (Dunwell 1995) also have no northern edges, though this need not imply contemporaneity of field system and fort. West of Bo'ness, the cliff is fronted by mudflat sediments that formed before the Antonine occupation and a 'Roman coastline' can be defined with reason (Bailey 1995b; 1996; Bailey & Cannel 1996) (illus 2). Whether coastal erosion was a concern to the Roman army is unknown, although James (2003) reports a putative breakwater of possible Roman age in archaeological survey of the inner Forth.

RIVER VALLEYS AND GEOMORPHIC ACTIVITY

Inland of the Firths the Wall takes advantage of high ground above the Rivers Kelvin and Carron. These valleys are each over a kilometre wide and are both infilled with great thicknesses of coarse sands and gravels deposited at the end of the last glaciation. Incised by some 8–10m below these fluvio-glacial terraces – and so later in age – are much narrower ribbons of fine-grained silts and sands, only hundreds of metres across, forming floodplains, the products of overbank flooding by lower energy, often single-channel meandering rivers (Brown 1997). Frequently, such overbank deposits away from estuaries accumulated (aggraded) only in the later Holocene, over the last 6000 years (Macklin 1999), in phases of accelerated geomorphic activity, not necessarily regionally synchronous, when rivers were flushed by greater runoff and received much higher sediment loads from eroding streambanks and soils (eg Mercer & Tipping 1994; Tipping 1995a; 1998). In southern Scotland, the later Iron Age and Roman Iron Age is a critical period of heightened geomorphic activity (Tipping 1992; 1997a; Tipping et al 1999b).

In the Kelvin Valley (illus 1) overbank sedimentation, anticipated to have commenced in the Neolithic period, proved instead to have been largely complete before 4000 cal BC (Tipping et al, unpublished data). It is likely that overbank flooding had ceased to be significant at least 2000 cal years ago. There is no comparable stratigraphic evidence from the Carron Valley, but the intensively studied later Holocene sediment stratigraphy throughout the Forth estuary has no significant fluvial component (Sissons 1972; Robinson 1993; Holloway 2002). This geomorphic stability in the Roman Iron Age can be shown at the Antonine Wall itself because, at Shirva (illus 2), the Wall abandons the high ground and crosses the present-day Kelvin floodplain; why it does so is unclear. The Wall and the ditch were constructed on gravels debouching north from an alluvial fan, almost certainly inactive by the second century AD, at the same altitude as and leading to the contemporary floodplain. The ditch fill is a highly organic black fibrous peat and the absence of minerogenic sediment (Glendinning & Cameron 2002) probably indicates that the Kelvin was not prone to flooding in the early centuries AD. Instead, the floodplain would have been a rather boggy surface, not the cultivable mineral soil that is there today, but perhaps dificult to traverse only in the wettest years. Ellis & Gooder (2002) interpreted a very comparable stratigraphy as peat infilling a natural abandoned channel of the Kelvin rather than the Antonine ditch, but there is no other evidence that the river was multi-channelled or mobile at this late stage in its development.

Unusually for regions of the British Isles heavily settled by Roman times, central Scottish rivers seem not to have been highly active in the Roman Iron Age, and their catchments seemingly not actively eroding. This interpretation is supported within a small anonymous stream valley descending to the River Carron east of Rough Castle (illus 2; Hamilton et al 2002), which showed peat with very little eroded mineral matter to have accumulated above a stone-lined ford after *c* 600 cal BC, probably through the Roman Iron Age. Lake basins provide other data sources on the intensity of soil erosion (Edwards & Whittington 2001). There is little evidence from those studied in the region that this was a significant problem in the Roman Iron Age except at Black Loch in Fife (Whittington et al 1990), and the now-infilled lake surrounding the early historic Buiston crannog (Tipping et al 2000) (illus 1). At these sites, mineral soils were less eroded than organic basin-edge peats. At the peat basin at Greenyards, near Stirling (illus 1), the evidence for local soil erosion probably has no regional significance, Rideout (1996) relating this to construction of fortifications.

In many ways the excellent preservation of the Wall up to and sometimes within rivers and streams emphasizes the stability of these catchments in contrast to ones further south in northern England and southern Scotland (Potter 1976; 1979; Tipping et al 1999b). The interpretations by Hanson & Maxwell (1983a) at Inveravon of large, possibly Roman, building stones visible on the present channel floor – similarly of stones on the crossing of the Kelvin at Balmuildy (but see Bailey 1996 for a note of caution here), and the discovery of the Cramond lioness barely concealed by sediment in the River Almond (Hunter & Collard 1997) – are very intriguing because in each case the stones have not been concealed by later fluvial sediments. The stones may, of course, have been re-exposed by scouring in recent years, but equally may indicate the low sediment loads of these rivers. This interpretation is not to deny that flowing water or waterlogging of stretches of the Wall presented engineering problems – as at Beancross (Bailey 1995b) and Peel Glen (Wood 1989), near Rough Castle where the *agger* may have been raised above the marsh (Keppie 1979), and at Brewer's Fayre, Falkirk, where standing water was perhaps sufficient to render valueless the construction of a ditch (Dunwell et al 2002) – or that construction or dismantling of the Wall and associated buildings at times created such problems, as at the Falkirk hypocaust excavated by Keppie & Murray (1981), or the Wall at Tollpark (Wilkes 1981) where the locally unstable turf structure may have been buttressed on a wet slope by kerbstones. Rivers did not cease to flow, and rivers and streams had to be crossed by the Wall (Bailey 1996) but floods were not necessarily a major problem in construction or land use. Any absence of Roman archaeological features on the floodplains of the Kelvin and Carron is probably to be explained by post-Roman sedimentation and not by the avoidance of them during the Antonine period.

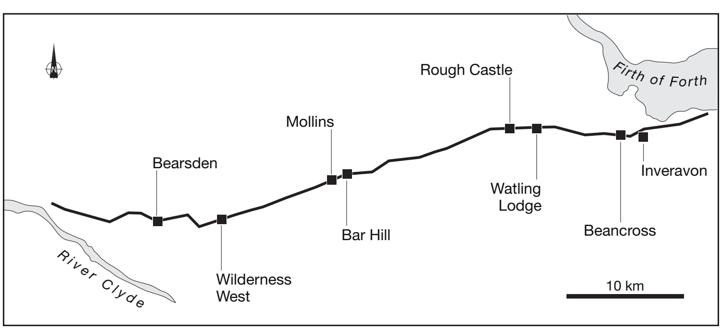
CLIMATE AND CLIMATE CHANGE

The limited evidence for accelerated geomorphic activity might, given the close link between climate change and fluvial response (Macklin & Lewin 2003), imply that climate in the second century AD was mild, dry and less stormy. This appears to be the case from palaeoclimatic data (Lamb 1981; 1982; Turner 1981). Much recent work has sought to identify significant shifts in precipitation within the region around the Wall (Barber et al 1993), developing analyses which seek to identify radiocarbon-dated hydrological changes within large raised mosses (Barber 1982), best explained in such contexts as being generated by rainfall. Stoneman's (1993) analyses in central Scotland describe a sustained period of quite uniformly dry climate from the first half of the first century AD for some 400 cal years, a period typified by neither extreme wetness nor severe aridity, and similar results have recently been developed for the Pentland Hills (Langdon et al 2003). More closely temporally constrained analyses of the short period around 100 cal BC (Langdon & Barber 2004) also show the region to have been relatively dry then and to have continued to be dry. This climatic stability must be one reason for the stability of the physical landscape. Crone (2000) has plausibly suggested that the sustained dry climate facilitated through lake level lowering the primary construction of the Buiston crannog in Ayrshire in the first two centuries cal AD. These conditions deteriorated after cal AD 400–450, and in events in north-west Europe that have attracted the attention of recent workers, climatic stress is being reconsidered as causal in Roman retreat from Britain (Jones 1996) and in the Roman decline and fall in general (Brown 2001). But there is currently no reason to consider the strategic decisions of the Empire in our period in our region to have been influenced by changes in climate (Dark 2000).

SOILS

The Antonine Wall is the largest turf structure in the British Isles. It is not surprising, therefore, that the soil cover on the Wall and how the builders of the Wall used this has been central to many interpretations of relative chronology, construction and function.

The varied rock types along and near the Wall give rise to parent materials sharply contrasting in drainage, nutrients and usefulness. These differences are then compounded by topographic contrasts principally influencing soil waterlogging. The majority of parent materials in central Scotland provide soils that are clay-rich and poorly drained, but not strongly acid. Most soils are still well-mixed and biologically active brown forest soils (a more acid equivalent of English brown earths) but often waterlogged (gleyed) to some extent. The formerly calcareous till-covered lowlands were probably decalcified early in the Holocene period (Tipping et al 2000). Acidification can lead to podsolization. Podsolic turves were retrieved from Bar Hill and Mollins (illus 3), both in contexts dated a few decades prior to Antonine occupation (Boyd 1984a; 1985) and are known from beneath contemporaneous structures elsewhere (Romans & Robertson 1983). But podsols can also have been formed and then destroyed by cultivation before incorporation as turves (Davidson & Carter 1997). Podsols are today most abundant in the uplands (Grieve 1993), where the plough has not reached.



ILLUS 3 Archaeological sequences on and close to the Wall used in the interpretations of soils and pedogenic change

Part of the acidification process in dry soils is a change in the acidity of surface organic matter accumulation, from mull to mor. Mate (1995) attempted to use this change as a chronological control for the development of a field system at Rough Castle (illus 3), in suggesting that turves cut to construct field walls early in the sequence were less acid than turves used to build field walls later. This is a nice idea for developing a relative chronology, although this process can be reversed by some vegetation changes (Miles 1985), and may work at a local scale if the sources of turf in walls remained the same. However, Mate sought to develop an absolute chronology for the field system by suggesting that the shift to mor soils occurred in the early–mid Iron Age, associated with climatic deterioration (eg van Geel et al 1996). This may also be correct at this site, although very little dating evidence was obtained to support the contention, but such a pedogenic change is strongly dependent on site-specific thresholds and cannot be used as a general model for the Wall.

In wetter parts of the landscape, the long-term trend in soils is to increasing organic matter accumulation, clay translocation and waterlogging. Peaty topsoils develop on poorly bioturbated soils and brown earths change to gleys. Waterlogging eventually leads to peat accumulation. In central Scotland, peats are commonly large dome-like raised mosses originally several kilometres in diameter and several metres thick. These developed on impermeable surfaces of 'carse' clay across almost all of the upper Forth valley (Cadell 1913) and on the 'carse' surfaces of both east and west coasts where most formed around 5000 cal years ago. Raised mosses were also abundant inland within hollows on equally impermeable clay-rich till where many began to accumulate at the beginning of the Holocene period (Parkyn et al 1997). They presented no direct obstacle to the constructors of the Wall, who selected the substantially drier hilltops when possible, but the former extents of these mosses and their merging together in long interlinked chains of raised moss, valley peat and lochan extending for several kilometres south of the Wall and stretching south across the damp plateaux to the Southern Uplands (illus 1; Dickson et al 1976; Dickson 1980; 1988) is often underestimated in the present landscape where all have been cut over and many have been completely destroyed.

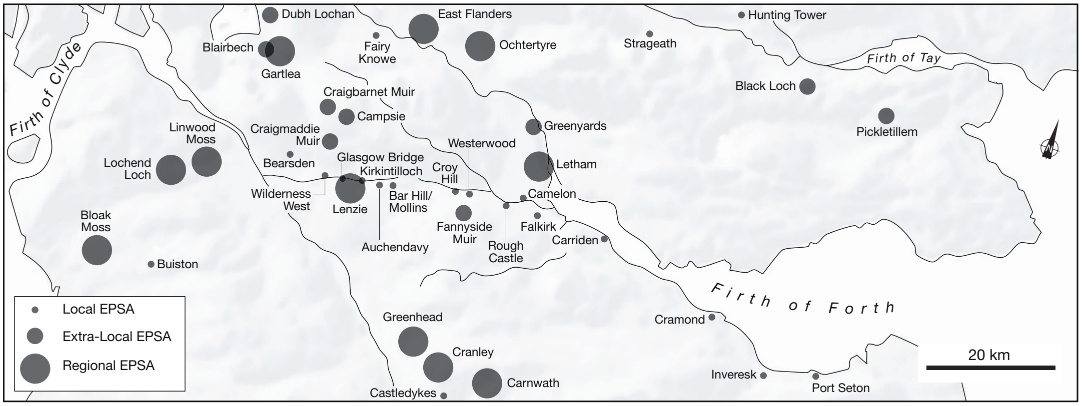
Blanket peats are unrelated to raised mosses, found in contrasting hydrological settings, the end-product of processes that impede drainage on formerly well-drained sites and under high rainfall. There is no evidence that blanket peat grew on the low hills traversed by the Wall: turves incorporated into the Wall rampart occasionally have organic surface horizons but these are not peats, but blanket mire that grew from before the second century AD high on the Campsie Fells and Kilsyth Hills which confronted Roman soldiers across the River Kelvin (illus 4; Eydt 1958; Dickson, J H 1981; Stewart 1983).

The course of the Wall was across predominantly dry and well-drained soils, built in a period of low rainfall. The soils along the Wall are today among the best in Scotland for arable agriculture (Bibby et al 1982), and this may have been an important consideration in the Wall's location and certainly in the development of the pre-Antonine Gask frontier (Hanson 1997). Hanson's (1978) calculations that consumption of turves would have had negligible impact on the the productivity of the surrounding land indicates that construction did not render unsustainable the soil resource, although Mate (1995) argued that such calculations ignore the consumption of turves for native buildings and field walls prior to the second century AD, and more of the landscape may have been scalped than we assume. A central issue in environmental archaeology on the Wall is the spatial contrast in the use of turves in rampart construction (illus 3; Macdonald 1934; Breeze 1974; Keppie 1974). The Wall rampart east of Watling Lodge, as well as westernmost sections, was in general constructed not with cut turf but with earth, only revetted or 'cheeked' with thin skins of turf or clay. These differences have often been explained in terms of the spatial patterning of vegetation and land uses, Macdonald (1924; 1934) suggesting that the 'carse' clay soils of the Forth Coastal Plain would have supported dense woodland with no grass sward and the till soils further west yielding good turves from open moorland. Maxwell (1989) suggested that the scarcity of good cohesive turves occurred in areas of arable land where the plough had disrupted the grass sward or where turves were poorly developed, with few binding grass roots, in areas of heath or woodland. Bailey (1995a) thought it improbable that the Wall on the Forth Coastal Plain could have been in such a highly specialized arable landscape and argued that contrasts in what the rampart was built from represented changes in design, the Wall east of Watling Lodge being added later. Our synthesis of pollen analyses in a later section suggests that large-scale arable farming may, indeeed, have limited available turf. To these different suggestions might, if the interpretations of Mate (1995) are correct, be added the possibility that turves were too thin to be used in areas heavily utilized and scalped in the years before Antonine occupation, although the well-preserved turves in the rampart at Rough Castle (MacIvor et al 1980) suggest this not to have been a problem at this site. Recent excavations have shown that the distribution of turves and earth in the east has more detailed patterns (Bailey 1995a): there are sections built with earth and sections built of turves at Inveravon (Dunwell & Ralston 1995) and, at Beancross, the use of turves has been identified (Bailey 1995b). Nevertheless, interpretations largely assume only a more localized, smaller-scale differentiation of land uses to have determined turf selection (Dunwell & Ralston 1995).

There have been very few scientific analyses of the turves themselves, despite these providing the clearest and simplest ways of identifying their sources. Micromorphological analyses of turves have not been attempted. There are frequently very careful descriptions of the arrangement, stacking and numbers of turves in an excavation but, far too infrequently, it appears, have the comments of a soil scientist been sought. Identifications of plant remains have not as yet yielded the data promised from the analyses by Dickson & Dickson (1988; 2000) at Bearsden (illus 3), where both plant remains and pollen showed the source of turves to have been boggy ground within heaths, land that might have been cleared of trees but was still unimproved rough pasture. The pollen analysis of soils has severe interpretative problems (see below) and no entirely secure analyses have been made from turves preserved from the Wall. Newell (1983) tentatively characterized turves at Wilderness West (illus 3) as deriving from a grassy heath, some distance from birch woodland. Boyd's (1984a; 1985b) analyses from turves at Bar Hill and Mollins are from pre-Antonine ditches into which turves were cast, and so may not be representative of where turves in the Antonine rampart were sourced, but they are closely comparable to those at Wilderness West, from beneath a grazed grassy heath. These apparent similarities in pollen assemblages from turves at several sites along and near the Wall on the central section of the Wall, facing the high ground of the Campsie Fells, might suggest a uniform source for turves but they do not allow a specific source to be defined. It has yet to be demonstrated that these similarities are not simply the product of differential destruction of pollen in environments inimical to analysis, such that *Calluna* (ling heather) and Poaceae (grass) pollen grains dominate the surviving assemblages.

VEGETATION COVER

This section focuses on data obtained by pollen analysis (illus 4). Although the taxonomic precision of pollen analysis is poor, plant communities, habitats and landscapes are best understood from these analyses because plant macro-remains at sites of human habitation are probably biased by the selection of plants for particular needs.



ILLUS 4 Localities used in the interpretations of vegetation and land use change. Differences between localities in effective pollen source areas (EPSA) are emphasized although the radii of circles around sites are schematic and not indicative of the actual EPSAs

In reconstructing vegetation cover before, during and after Antonine occupation we have to synthesize pollen data from deposits that are very hard to compare. Data from large raised mosses cannot easily be related to those from, for instance, the fill of an Antonine ditch, and the ditch fill cannot be compared to analyses from buried turves or soil samples at the same fort. The data appear the same, and pollen diagrams look depressingly similar to the uninitiated, but there are fundamental contrasts in pollen recruitment and taphonomy, and different interpretative strengths and weaknesses.

Pollen analysts in the region have most frequently analysed the thick, continuously forming peats of raised mosses (illus 4 and Table 1). The thickest and best temporally resolved sediment sequences tend to be in the centres of these mosses, but sampling these means literally walking away from the dry soils that are usually of most interest to the analyst. The more distant the sampling site is from agricultural activity, the less well can this be sensed and described, and an underestimated difficulty is estimating how distant sampling sites were from dry land when the mosses were intact, before their recent destruction (Parkyn et al 1997). In particular, the absence of cereal pollen grains from such pollen records need mean nothing. The result is that pollen analyses from such sites are generalized impressions of the landscape: specific or local details cannot be retrieved (Tipping 1997b; Huntley 2000). Pollen grains can only reach the middle of the moss by being blown in the wind, and this mechanism skews representation to the subpopulation of plants that disperse pollen through the air, particularly trees. At the same time, the representation of woodland on dry soils can be distorted because, particularly at times of relative aridity, trees colonize peat surfaces (Dumayne-Peaty & Barber 1998). Interpretation of woodland regeneration when only wetland trees expanded onto the peat surface bedevil the literature.

Serious distortions also occur in the representation of *Calluna* (ling heather). Very large increases in proportions of this pollen type are common in our period. *Calluna* grows not just on dry heath soils but on the surfaces of raised mosses, meaning that increased growth or pollen production of *Calluna* on a moss will reduce the proportions of dryland pollen. There are statistical mechanisms for reducing this effect in pollen diagrams, by assuming that *Calluna* only grew on bog surfaces (Dumayne 1993b) but this assumption, from soil pollen analyses, is known to be wrong. Ramsay (1995) chose not to make this assumption, and this might have been

TABLE 1
Characteristics of Roman Iron Age pollen assemblages at sites in central Scotland (1) outside the Wall and (2) inside the Wall

Site	*Author*	*Site type*	*EPSA*	*Depth*	*^{14}C assays (no)*	*Temporal resolution*
1. Outside the Wall						
Kilpatrick and Campsie Fells						
Campsie	Eydt 1958	Blanket bog	Extralocal	175cm	0	
Craigbarnet Muir	Stewart 1983	Blanket bog	Extralocal	200cm	1	Low
Lomond Basin						
Blairbech Bog	Dumayne-Peaty 1998	Raised moss	Extralocal	240cm	3	High
Dubh Lochan	Stewart et al 1984	Valley mire	Extralocal	490cm	5	Low
Gartlea	Ramsay 1995	Raised moss	Extralocal to regional	300cm	0	High
Loch Lomond	Dickson et al 1978	Lake	Regional	494cm	13	Low
Forth Coastal Plain						
Camelon	Proudfoot 1978	Soil	Local	n/a	Archaeo-logical	n/a
East Flanders	Turner 1965; 1983	Raised moss	Regional	400cm	6	High
Greenyards	Rideout 1996	Valley mire	Extralocal	275cm	4	Low
Letham	Dumayne-Peaty 1998	Raised moss	Regional	180cm	3	High
Ochtertyre	Erdtman 1928	Raised moss	Regional	345cm	0	Low
Fife Lowlands						
Black Loch	Whittington et al 1990	Lake	Extralocal	750cm	10	High
Hunting Tower	Woolliscroft 2000; 2002	Soil	Local	n/a	Archaeo-logical	Low
Pickletillem	Whittington et al 1991	Lake	Extralocal	800cm	11	Low
Strageath	Frere & Wilkes 1989	Ditch fills	Local	n/a	Archaeo-logical	Low
Midland Valley						
Craigmaddie Muir	Dickson 1981	Valley mire	Extralocal	150cm	0	Low
2. Inside the Wall						
Midland Valley						
Bar Hill	Boyd 1984; 1985a; 1985b	Soil	Local	n/a	0	n/a
Bearsden	Dickson et al 1979; Knights et al 1983; Dickson 1989; 1990; Dickson & Dickson 2000	Soil	Local	n/a	0	n/a
Fannyside Muir	Dumayne-Peaty 1998b	Blanket bog	Extralocal	300cm	2	High
Glasgow Bridge	Dunwell & Coles 1998	Ditch fill	Local	100cm	2	High
Kirkintilloch	Dickson 1995	Ditch fill	Local	n/a	0	n/a
Lenzie	Ramsay 1995	Raised moss	Regional	260cm	6	High in Roman Iron Age
Mollins	Boyd 1984; 1985a; 1985b	Soil	Local	n/a	0	n/a
Rough Castle	Moffat 1995	Soils	Local	n/a	0	n/a
Westerwood	Tipping 1994–5	Soil	Local	n/a	0	n/a
Wilderness Plantation	Newell 1983	Soil	Local	n/a	0	n/a

Table 1
Characteristics of Roman Iron Age pollen assemblages at sites in central Scotland (1) outside the Wall and (2) inside the Wall (*cont*)

Site	*Author*	*Site type*	*EPSA*	*Depth*	*^{14}C assays (no)*	*Temporal resolution*
Southern Valleys and Plateaux						
Bloak Moss A	Turner 1965; 1970; 1975; 1979; 1981; 1983	Raised moss	Regional	350cm	7	High
Carnwath	Fraser & Godwin 1955	Raised moss	Regional	150cm	0	Low
Cranley	Dumayne-Peaty 1999	Raised moss	Regional	300cm	3	High
Greenhead	Davies & Tipping, unpublished	Raised moss	Regional	450cm	10	High
Buiston	Mills 2000	Soils	Local	n/a	Archaeo-logical	n/a
Castledykes	Tipping 1994–5	Ditch fill	Local	n/a	Archaeo-logical	n/a
Linwood Moss Cottage	Boyd 1982	Valley mire	Regional	370cm	3	Low
Lochend Loch	Ramsay 1995	Raised moss	Regional	240cm	8	High
Walls Hill Bog	Ramsay 1995	Raised moss	Regional	220cm	7	High
Forth Coastal Plain						
Eskbank Nurseries	Moffat 1985	Post hole fills	Local	n/a	1	Low

wiser were it not for the palaeoclimatic evidence (above) for increasing relative aridity into the Roman Iron Age that induced conditions of low water table on raised moss surfaces, ideal for *Calluna* expansion (Stoneman 1993; Langdon et al 2003). There is no right answer here, but these decisions mean that the two major recent contributions to the literature are not directly comparable.

Valley mires are peat sequences that often combine continuity of record with a greater sensitivity to small-scale spatial patterning because they tend to have smaller diameters, are closer to dryland soils and because much of the pollen deposited derives by streamflow from slopes surrounding the basin (Edwards 1979; 1982; Pennington 1979). Small lake basins share these qualities. Stream transport in landscapes subject to intense soil erosion can mean that pollen grains are also eroded and non-contemporaneous (Tipping 1992; Edwards & Whittington 2001), as at Black Loch and at Buiston (above), and in Loch Lomond after the Roman Iron Age (Dickson et al 1978), but this is not a significant problem at most of the sites analysed here (Table 1). Blanket peat sequences (Eydt 1958; Stewart 1983) probably describe very small patches of ground, perhaps tens of metres around (Bunting 2003). They have this in common with analyses from stratified ditch fills on the Wall (Table 1). Much less easily interpretable, if interpretable at all, are analyses, often single or ‘spot’ samples, from old ground surfaces and soils. Problems include the poor preservation of pollen grains and differential destruction of particular types (eg Newell 1983; Tipping 1995b, at Tayavalla), the likelihood that many pollen grains are reworked and the absence of secure stratigraphic information (Davidson et al 1999; Tipping et al 1999a; Long et al 2000). Techniques to resolve these (Tipping et al 1994) have not been used in analyses on the Wall, and the oft-quoted but poorly understood soil pollen analyses (Table 1) are here treated with caution.

Pollen records that describe moderately small areas around them are regarded here as most appropriate to archaeological interpretation. Records depicting small areas of the landscape can be combined to describe larger landscapes but records describing large areas cannot be deconstructed to depict smaller, more 'patchwork' landscapes. Because peat surfaces support pollen-producing vegetation it is not as straightforward as with lakes to define where most pollen grains come from – the effective pollen source area (EPSA) – but here it is assumed that the relations between basin diameter and EPSA are much as Jacobson & Bradshaw (1981) defined them for lakes: local EPSAs reflect plant communities within 20m of the sampling site; extralocal EPSAs depict areas between 20m and several hundred metres from the sampling site; region-scale EPSAs describe areas at greater distances (Table 1 and illus 4).

Table 1 also contains summaries of the dating controls in pollen analyses. There is no feasible way in which analyses not from sealed archaeological features on the Wall itself can be defined as relating to an occupation phase measured in decades. No convenient Icelandic tephra fell across the region, and wiggle-matched radiocarbon dating (Dumayne et al 1995) would still not have the required precision. So we can describe general trends in vegetation and land use occurring from the last few centuries BC to the early centuries AD but we cannot define an Antonine horizon. For example, Dunwell & Coles' (1998) radiocarbon assay on peat from the base of the Antonine Wall yielded a calibrated age of AD 57–195 at 1-sigma but 30 BC to AD 250 at 2-sigma. Tipping's (1994) review highlighted the paucity of radiocarbon dating controls on pollen analyses before the mid-1990s and this deficiency affects many analyses here. The detail with which a peat or lake stratigraphy is subsampled and analysed is described by the term 'temporal resolution' in Table 1; without good dating controls this cannot be measured but subjective estimates (low/high) are made.

The uplands north of the Wall (Kilpatrick and Campsie Fells and the Fintry and Ochil Hills) are poorly served by detailed analyses. They were probably heather-clad and treeless by the Roman Iron Age (Eydt 1958; Stewart 1983), though it is unclear whether deforestation was through climatic stress or by grazing pressures.

In the Lomond Basin west of the Campsie Fells, nestling in hollows close to Loch Lomond within poorly drained gley soils of drumlinized till, are the key sequences of Gartlea (Ramsay 1995) and Blairbech Bog (Dumayne-Peaty 1998b). They lie within 2km of each other south of Gartocharn and should share the same EPSA. The Blairbech sequence has three radiocarbon assays, two closely bracketing the Roman Iron Age; the sequence at Gartlea was not radiocarbon-dated. In the last century BC or so (*c* 225 cal BC), all types of woodland around Blairbech Bog were reduced and grazed grassland became very common. Perhaps before the Agricolan advance this expansion of pasture had ceased and declined in vigour, though abandonment (Dumayne-Peaty 1998b) is thought here to be too extreme a description. Ramsay (1995) argued for the opposite trend in the Roman Iron Age at Gartlea, that is for extensive woodland clearance, an interpretation that cannot currently be tested and one that shows the difficulty of analyses with no independent age controls. Slightly to the north, on Lomondside, the comparatively poorly resolved but radiocarbon-dated analyses at Dubh Lochan suggest very limited human activity until small-scale clearance, dated imprecisely to after *c* cal AD 300 (Stewart et al 1984).

In the upper Forth valley, an extension of the Forth Coastal Plain, pollen diagrams by Erdtman (1928) and Durno (1956) are of historic value only; although made by some of the pioneering figures in the science, they are inadequate. Turner's (1965) diagram from East Flanders was also ground-breaking, but interpretation is hampered by an inconsistent series of ^{14}C assays and high errors around the mean radiocarbon ages. Turner's (1983) interpretation of the chronology is accepted here, in which small and temporary later prehistoric clearance events within oak–hazel–birch dry woodlands were transfigured early in the first centuries AD (cal AD 71–591 at 2-sigma) by a single large-scale, extensive clearance. What this intense deforestation phase was for cannot be described from a pollen site distant by more than a kilometre from the nearest farm land, and Turner's dismissal of an arable component is unwarranted. The skeletal pollen analyses depicting the local landscape at Greenyards, near Stirling (Birnie 1996), cannot be interpreted too closely because they are from a very compressed peat stratigraphy and so are lacking in temporal resolution, and are possibly but not obviously affected by errors in radiocarbon dating. They suggest a mixed farming landscape from the early Iron Age (1627–1950 cal BC), and the strong and seemingly abrupt expansion of cereal production and grassland in the first two centuries cal AD, radiocarbon-dated to cal AD 64–339, apparently continuing into the early historic period.

Letham Moss, north of Stenhousemuir and 6km north of the Wall, is one of the largest raised mosses on the Forth Coastal Plain. The pollen record (Dumayne 1992; 1993a; 1993b; Dumayne-Peaty 1998a; 1998b; 1999) is insensitive to small-scale landscape change but records major disturbances. An extensive but also very rapid deforestation event affecting dry hazel–oak woods and wetter woods was radiocarbon dated to 345–108 cal BC (Dumayne et al 1995). Despite the region-scale EPSA, pollen grains of *Hordeum*-type (barley) are frequently recorded, and surrounding soils are likely to have been extensively cultivated, perhaps better-drained ones on fluvio-glacial terraces. What was not ploughed appears to have been grazed, and the few surviving dry woods may have had to be protected [see Boyd's (1984b) suggestion of hawthorn (*Crataegus*) hedges at Bar Hill]. Dumayne (1993b; Dumayne-Peaty 1998b) suggested that the Agricolan and Antonine advances may have intensified agricultural activity but the palynological evidence for this is not strong: the interpretation here sees this activity as continued but not renewed. Cereal production is argued here, however, to have significantly declined at *c* cal AD 100 (but any time between 20 BC and AD 220), although areas of pasture perhaps smaller than before were maintained until secondary hazel woodland replaced some of these at *c* cal AD 300 (cal AD 180–420 at 2-sigma). The pre-Antonine native settlement at Camelon (Proudfoot 1978) probably lies within the Letham Moss EPSA and, though of uncertain value, analyses there depict an almost treeless grazed pasture (Dimbleby & Sheldon 1978).

Within the rich arable lands of the Fife Lowlands, and those of the lower Tay, soils within or close to the Gask Frontier (Ramsay 2000; Wolliscroft 2002) and Strageath (Butler *in* Frere & Wilkes 1989) were also treeless in pre-Antonine and Antonine contexts. Larger-scale landscapes are described by the sequences at Black Loch and Pickletillem (Whittington et al 1990; 1991). The latter sequence is very poorly resolved but the Black Loch sequence is superbly detailed but also controversial. The sequence was argued by Whittington & Edwards (1993) to provide evidence for Roman military activities to have provoked native agricultural collapse and settlement abandonment. The palynological evidence comes from the best resolved of four sediment sequences (BLI) in which a low-intensity mixed farming regimen in later prehistory was apparently abandoned as hazel woodland colonized the surrounding slopes. Whittington et al (1990) and Whittington & Edwards (1993) considered that woodland regeneration occurred between 3 BC and AD 521, making the event on balance of Roman Iron Age date, but the radiocarbon assays were not calibrated. Indeed, this horizon was not directly radiocarbon dated but is interpolated between assays. Calibration to 2-sigma, using the CALIB 3.03 programme, and resultant interpolation indicates the event to have an age sometime between 125 cal BC and cal AD 20, making it much more likely to be unrelated to Roman presence. Reduced proportions of agricultural indicators in the pollen record persist until the Early Historic period, estimated via calibration to between AD 640 and 910. However, there are grounds for questioning the reality of woodland regeneration because no such event was identified in the more poorly resolved but nevertheless radiocarbon-dated sequence at BLII from the same lake, and the patterns of sediment inwashing and lake level fluctuation in the later Holocene, beautifully reconstructed by Whittington et al (1990), make it at least possible that the pollen record does not accurately depict contemporaneous vegetation or land use changes but the inwashing of reworked pollen.

The Wall divides the Midland Valley, and the distinction between outside and inside the Wall is probably ecologically artificial. Four kilometres north of Balmuildy, beyond the Wall and 150m higher, Craigmaddie Muir is a peat-filled basin that, perhaps like many on the slopes rising to Strathblane and the Campsie Fells, has accumulated for much of the Holocene period. This site contains little palynological information on the Roman Iron Age, but intriguingly this might be because the peat was cut for human use (Dickson, J H 1981). It is tempting, of course, to link this activity in this sort of location on soils today sufficiently acidic and well-drained to have supported *Calluna* heath in the absence of agricultural improvements, to the apparent cutting of heathland turves for the Wall at Bearsden, Wilderness West and Mollins (above).

Uncertainties in the interpretation of soil pollen analyses mean that Boyd's (1984a) suggested pre-Antonine vegetation and land use changes around Mollins and Bar Hill, and his specific suggestion that the Midland Valley was a landscape in agricultural decay before Antonine occupation, remains conjectural. It contrasts with the stratigraphically secure pollen record in this area from Letham Moss (above). Moffat's 'spot' analyses from pre-Antonine soil contexts at Rough Castle (*in* Mate 1995) suggested a rather unvarying vegetation before Antonine occupation of grassland, damper areas and *Calluna* heath amid a secondary scrub of birch, hazel and willow and some larger trees of oak and elm, and Dunwell & Coles (1998) also inferred from abundant, probably inwashed and reworked *Calluna* and Poaceae pollen at the base of the Antonine ditch near Glasgow Bridge that soils during occupation supported heath. From a ditch believed contemporaneous with Antonine occupation at Westerwood, Tipping (1994–5) found little evidence for *Calluna* heath, the local landscape covered by a light scrubby birch–hazel woodland with rare oak trees and a grazed grassland, and at Union Street, Kirkintilloch, sediment interpreted as contemporaneous with Roman occupation contained high amounts of birch and hazel pollen representing a significant if light woodland (Boardman & Dickson 1995). There is only limited evidence for cereal cultivation in pollen records from the Midland Valley. Dunwell & Coles (1998) found cereal-type pollen grains, suggesting some cultivation at Glasgow Bridge, but these were not defined to pollen taxon and may represent species of wild grass growing in the ditch, as suggested for grains of *Hordeum*-type (barley) pollen further east at Union Street, Kirkintilloch (Boardman & Dickson 1995).

Newell (1983) suggested from immediately post-Antonine ditch fills at Wilderness West that birch trees colonized what had been open ground, a symptom of decay and abandonment, and Dunwell & Coles (1998) also demonstrate tree colonization near Glasgow Bridge, first of birch and then, by cal AD 220–340, of alder (*Alnus*) and slower growing oak (*Quercus*), maintained around the site until cal AD 420–550 (1-sigma). Birch is a key taxon in halting or reversing soil acidity (Miles 1985) and may have been important in facilitating the regrowth of a very substantial local population of oak trees on former heathland.

Lenzie Moss (Ramsay 1995) is the nearest pollen sequence with a region-scale EPSA to the Antonine Wall, only 2km south of Glasgow Bridge and equally close to the sequences at Wilderness West and Union Street, Kirkintilloch. The EPSA of the record at Lenzie encompasses the landscape described by these local records. Substantial and seemingly sharp reductions in tree pollen percentages occurred prior to Antonine occupation (94 cal BC–AD 112; Ramsay 1995) and falls occurred in the values of both dryland and wetland trees. However, proportions of oak (*Quercus*) pollen had been declining, and those of grasses that might be expected to have replaced this woodland had been rising gradually from before *c* 500 cal BC. Because *Calluna* expansion at this site distorts the representation of other taxa (above), it is possible at Lenzie that the scale of deforestation is exaggerated. A minimalist interpretation is possible in which mature oak woodland was removed from the early Iron Age to create, by the time of the Antonine occupation, a landscape of fields with crops and domestic stock, possibly hedged (Boyd 1984b) within an open, secondary birch–hazel woodland. Cereal-type pollen grains were recorded at Lenzie too infrequently to judge the extent or continuity of cultivation. An abrupt reduction in grass pollen and the cessation of pastoral indicator herb taxa, probably the best measures of agricultural activity from raised mosses (Dumayne 1993b), strongly suggest that farming was locally abandoned well after Roman withdrawal, at cal AD 447–607 (Ramsay 1995).

Fannyside Muir (Dumayne-Peaty 1998b) is 14km ENE of Lenzie Moss and 4km south of Castlecary fort. The site perhaps shares in part the EPSAs of Lenzie Moss and Lochend Loch Bog in the Southern Valleys and Plateaux, evaluated below. The same mid–late Iron Age trend to sustained woodland clearance can be demonstrated, from perhaps 230–540 cal BC , and seemingly for pasture. This clearance appears to have been intensified, from a more securely dated horizon at 90 cal BC–AD 220, not clearly within the Roman Iron Age, although *Hordeum*-type (barley) pollen is recorded only from the second century AD. Dumayne-Peaty (1998b) interpreted the sequence after *c* cal AD 170–420, on balance post-Antonine, as depicting gradual tree regeneration but there is no clear evidence that dryland soils were lost to woodland.

The Midland Valley merges imperceptibly to the Southern Valleys and Plateaux. South-east of Lenzie and south-east of Fannyside Muir, Ramsay's (1995) analyses at Lochend Loch Bog describe the same landscape as these sites. But, as at Lenzie Moss, the abrupt expansion of *Calluna* in the late Iron Age to values >50% at 354–63 cal BC, probably on the moss surface, distorts the depiction of the wider landscape. Beyond this screen of bushes, however, the dryland soils were gradually, perhaps sporadically, cleared of oak and birch woodland from at least the later Bronze Age and more lastingly from *c* 500 cal BC, seemingly for pasture and not for crops, although the problems of recording cereal pollen grains from raised mosses has been stressed. This problem exists too with analyses from the raised Greenhead Moss, 20km south of Fannyside Muir and 24km south of the Wall (Davies & Tipping, unpublished data). Although the sequence is a complete Holocene record, there are no radiocarbon assays on sediments younger than the late Bronze Age. The Iron Age landscape is described as one in agricultural recession, with lower levels of human activity than in the Bronze Age, with anthropogenic indicator taxa particularly uncommon in the late Iron Age from *c* 400 cal BC to 300–100 cal BC, and there is little sign of economic revival until after Roman withdrawal. Further south still, 35km into the interior of the Southern Uplands at Cranley Moss, a not dissimilar pattern of partial dereliction in the Roman Iron Age is depicted (Dumayne-Peaty 1999). Substantial, though partial, pastoral agricultural impacts (the record is skewed to this as in other large raised mosses) occurred from 800 to 600 cal BC and were intensified at 440–240 cal BC, but were then at least partly abandoned as birch–hazel woodland cover expanded. In our interpretation, this occurred before or during Roman intervention (from cal AD 1 to 180): Dumayne-Peaty (1999) argued for woodland regeneration from cal AD 136 to 353. Into this partly derelict landscape, the Flavian fort at Castledykes and its associated marching camps were built (Keppie 1994–5). Tipping's few analyses from a ditch fill, though potentially mixed and badly preserved, might depict the few tens of metres around this camp, treeless and farmed, certainly for animals and probably for crops.

South of the Clyde, Boyd's (1986) analyses from Linwood Moss Cottage are insufficiently resolved to allow interpretation. The adjacent Walls Hill Bog (Ramsay 1995; 1996), though poorly resolved through low rates of peat accumulation, is interpretable: *Calluna* here was not a dominant taxon. Sustained losses of oak occurred after 800–400 cal BC. Increases in grassland were distinctive after 600–100 cal BC and grazing indicators more prominent in the later Iron Age; again numbers of cereal-type pollen grains are insufficient to interpret. This peak in agricultural activity began to decline by 160 cal BC–AD 112, probably before Roman incursion, and this landscape appears to have been arguably abandoned by the second century AD.

On the poorly drained, drumlin and till-covered plateaux of Ayrshire, at the complex of raised mosses collectively called Bloak Moss, near Kilwinning (Turner 1965; 1970; 1975; 1979), human impacts before *c* 500 cal BC were small in scale and shortlived, with woodland regeneration almost complete between disturbance phases, but one of these developed seemingly gradually by *c* 300 cal BC to a more sustained and extensive clearance event. Cereal-type pollen is inevitably rare in such peats, although cereals were probably uncommon on such poorly drained soils, but grazing indicators are abundant. High amounts of *Calluna* grew on the moss surface from the first century AD but these do not distort interpretation here. Falling proportions of grazing indicator taxa show that this activity was in sustained decline by *c* cal AD 150, possibly before the Agricolan advance and probably before Antonine occupation. Recovery did not occur until well into the historic period. Six kilometres to the south-east, people began to invest in construction of the crannog at Buiston in the first two centuries AD (Crone 2000), and although no regional reconstruction of land use change was possible from the disturbed laustrine sediments, the local gley soils were grazed though probably not cultivated (Mills 2000).

LAND USES AND LAND USE CHANGE: SYNTHESIS AND DISCUSSION

There can be no doubt now that the Antonine advance and colonization took place within a farmed landscape. Every pollen record shows, unsurprisingly, that woodland formerly covered all of the region. But every pollen record in this review shows that disturbance of the woodland by farming communities had been happening for at least 2000 years before Roman incursion (Tipping 1994). In many localities the primary oak woodland had effectively been replaced by secondary species like birch, hazel and ash (*Fraxinus*) during the frequent phases of woodland regeneration. In other places, stands of oak woodland persisted or were maintained by simple forms of management to provide timber. Woods may have formed part of the agricultural landscape from an early period (Tipping 2002a).

Within these woods, small openings were created throughout later prehistory to raise stock and grow crops. No woodland clearance event before the mid–late Iron Age can be described as extensive or comprehensive. Trees and woods always remained somewhere close to farmsteads, and the landscape was predominantly wooded. It is unrealistic to define the duration of individual clearance phases because radiocarbon dating controls cannot measure these with precision. They may have persisted at one place for several human generations. Even this is unclear, however, because more frequent settlement shifts within the EPSA of a single pollen site will give the impression of sustained disturbance

(Edwards 1982). This problem has not been resolved because efforts have been concentrated on pollen analyses that depict landscapes at the region scale. There is a pressing need to reconstruct landscapes at much smaller scales from valley mire and small lake settings.

If settlements did not shift frequently, they may have been regarded by contemporaneous farmers as permanent, but actually each of these occupation phases is followed by woodland regrowth and at least a decline in economic activity. It is often not possible to identify settlement abandonment, partly because agrarian modifications to plant communities – such as the development of secondary woodland or the colonization of grasses by particular herbs – might have persisted (Buckland & Edwards 1984), and partly because in most instances there probably was no total dereliction. The prodigious investment in *landnam* brings with it a commitment to the land (Tipping 2002b). Despite Turner's (1975) pioneering attempt to define the spatial extent of openings around Bloak Moss, this has also not been achieved. We do not know how extensive later prehistoric clearings were: again this is a limitation of relying on single pollen diagrams to describe large areas. It may have been that each farm was isolated, separated from others by woods. The mapping of prehistoric field systems is not easy in the improved lowlands of central Scotland, and the extents of contemporaneous fields have not been demonstrated (Johnston 2002).

This picture changes in the 200–300 years before the Agricolan advance in most of southern Scotland (Tipping 1994; 1997a; 1997b; Huntley 2000). There is no evidence to support Turner's (1979; 1981) suggestion that this characteristic impact occurred earlier in northern England than in southern Scotland. Sufficiently resolved pollen records show that clearance phases became longer. In some localities there has been no significant woodland regrowth since the later Iron Age. The areas cleared may generally have become larger, and in several parts deforestation was total. Deforestation was, in many locations, also remarkably abrupt and decisive. This can be shown to have been true also for central Scotland (Ramsay & Dickson 1997). Tipping (1997b) has suggested that this scale of decision-making hints at the emergence of the regional tribal socio-political structures familiar to the Romans. As we have known for some time, there was no Caledonian forest (Breeze 1992; Dickson 1993; Tipping 1994), at least south of the Wall. Woodland still persisted, as the pollen records and samples of charred wood from excavations show, and there can be a high diversity in the wood assemblages (eg MacDonald & Park 1902; Hanson 1996; Dickson & Miller *in* Bailey 2000). Much of this woodland was a light scrub of birch, alder, hazel, willow, rowan, blackthorn and hawthorn, probably protected and possibly increasingly intensively managed, but large oaks still grew, also perhaps managed, to be used in construction, as at the Fairy Knowe broch (Barber 1998), the earliest crannog at Buiston (Crone 2000) and the hypocausted building at Falkirk (Dickson, C 1981). There is no evidence that the timber resource was depleted immediately before, during or after Antonine occupation (Hanson & Macinnes 1980).

Only at Greenhead, East Flanders and Lenzie Mosses (illus 4) did short-lived later prehistoric clearances fail to develop into more extensive and more enduring settlement phases prior to the first century AD (see above and Ramsay & Dickson 1997). At some localities it is uncertain, because of chronological imprecision, whether the commencement of this substantial economic expansion preceded Roman occupation (eg Fannyside Muir and Walls Hill; illus 4) but at most sites agrarian expansion commenced in the later Iron Age (Tipping 1994; 1997; Ramsay 1995; Dumayne-Peaty 1998b). The Romans sought dominion over an already farmed landscape, and one that was economically 'on the up'. The frequently intense debate in the past decade concerning Roman deforestation and its purpose on and near Hadrian's Wall (Hanson 1986; Barber et al 1993; Dumayne 1993a; 1993b; 1994; 1995; Dumayne & Barber 1994;

Tipping 1994; 1997; McCarthy 1995; Dumayne-Peaty 1998a; Dark 2000; Huntley 2000) has not arisen on the Antonine frontier. The reasons for economic expansion in this region cannot have been fuelled by the Roman presence but were a native development, although it remains unclear what the motivations were. Given the imprecision of radiocarbon assays it is not possible to detect differences in the timing of this major change inside and outside the Wall (although this division is meaningless as events were almost entirely pre-Agricolan) or south and north of the Forth–Clyde isthmus and between tribes who may have recognized this natural boundary (Maxwell 1989; Strang 1998). There is, however, the potentially significant pattern from Cranley, Greenhead, Walls Hill and Bloak Mosses on the Southern Plateaux (illus 4) that this economic vibrancy had also been lost by the end of the Iron Age, and that this part of the region was in economic decline when Roman forces first saw it. This possible pattern apart, it is not clear from pollen analyses that there were significant contrasts in the different landforms in the region in the later Iron Age.

At local scales, remnants of field systems are recorded archaeologically, though the processes of recent agricultural change means that they cannot be established as typical or common. Most are found in the drier east of the region (illus 4), although the significance of this is unclear. In addition, they are not dated. Mate's (1995) attempt at Rough Castle to define a chronology is best described as adventurous. The fort at Croy Hill has fragments of a field system but its relation to the fort is unclear (Hanson 1979), while a similarly fragmented series of ditches at Auchendavy (Hastie 2002) may be Roman. In the part of the region argued here to have been in economic decay, the putative pre-Antonine fields at Castledykes (Maxwell & Wilson 1987) are intriguing given the site-specific palynological evidence for cultivation as well as grazing (see above). Dunwell (1995) argued that the system at Carriden (see also Bailey 1997) may have been contemporaneous with Roman occupation, perhaps associated with the civilian settlement, though this has not been established, but the best known system at Inveresk (Thomas 1988; Bishop 2002), though close to another *vicus*, is multi-period with some elements having developed in later prehistory and some added after Roman occupation (Cook 2004). The Roman system is extensive, however, and Cook (2004) argues that it gradually evolved, perhaps from a pre-Antonine core. There may have been both arable and pastoral elements to the farming economy.

Traces of ploughed soils stratified beneath Roman structures are also recorded. A direct relation between native settlement and Roman occupation is often argued for, as at Callendar Park, Falkirk (Bailey 1995a), but at Cramond, Holmes (2003) argued that cultivation was separated in time from Roman settlement because a grassland sward seemed to have been criss-cross ploughed before Roman occupation. This perhaps tenuous argument has a resonance, however, in recent debates at sites on Hadrian's Wall where ploughing has been seen as ritual ground preparation rather than indicating cultivation (Wilmott 2003). Region-scale pollen records are very poor at defining the sophistication of rural economies: the nature of pollen recruitment means that most landscapes will be repeatedly and depressingly characterized as having mixed farming economies (van der Veen 1992). Cereal pollen will be so poorly detected at most sites in the region that nothing can be made of an apparent absence. This makes the pollen record at Letham Moss for extensive crop growing in the late Iron Age exceptional because of the limited dispersal of cereal-type pollen grains to a site like this and because the record describes such a large area of the Forth Coastal Plain. The evidence is confirmed locally in the poorly resolved sequence at Greenyards, and an association of intensive cereal husbandry on the better drained fluvio-glacial soils of the valley sides is very probable for the late Iron Age, indicated also from charred plant assemblages at Fairy Knowe, Buchlyvie (Boyd 1998), Camelon (Proudfoot 1978; Boyd 1988) and Port Seton (Haselgrove & McCullagh 2000).

Scientific analyses of turves used in construction of the Antonine Wall have not done enough to resolve their source and answer long-posed archaeological questions, but it seems at least likely that the soils of the Forth Coastal Plain produced poor turves because most had been cultivated (cf Maxwell 1989; Bailey 1995a); an exception may be the heath soils thought to have been cut as turves at Port Seton (Miller et al 2000). To the west, heath soils that were used in rough pasture were more readily available for construction, probably when developed on the volcanic soils of the Croy Ridge directly on site. But there is no evidence to suggest that extensive contemporary woodland anywhere along the Wall prevented the development of turves.

The cultivated soil at Cramond may have been replaced by grassland before Roman occupation (Holmes 2003). The broch at Fairy Knowe is argued to have been abandoned before the Antonine period (Main 1978). Region-scale pollen analyses at Letham Moss appear to indicate the cessation of crop-growing at around this time, although local-scale analyses at Greenyards appear not to show this. No other pollen diagrams in the region show changes comparable with, or as clearly depicted as, those at Letham Moss. In addition, there are very few soils or ditch fills at Antonine forts that contain cereal-type pollen (above), and the Antonine period charred plant assemblage at Union Street, Kirkintilloch, does not signify widespread local cultivation (Boardman & Dickson 1995). These observations tentatively suggest a decline in cereal production on and near the eastern section of the Wall in what had previously been a major grain-producing area. What this might represent, if indeed it is valid, is uncertain. It does not necessarily represent the abandonment by native farmers of the landscape near the Wall (cf Whittington & Edwards 1993), but neither does it suggest the exchange system suggested by Dickson & Dickson (2000) whereby Roman luxury items were bartered for native barley for the cavalry and their horses.

This suggestion is not contradicted by the beautifully delicate analyses of Roman diet at Bearsden (Dickson et al 1979; Knights et al 1983; Dickson & Dickson 1988; 2000; Dickson 1989; 1990) because the cereals prepared and consumed were species of wheat, and wheat probably had to be imported (Hanson 1997; Dickson & Dickson 2000). Indeed, the scarcity of evidence for locally grown wheat in the region strongly suggests that this must have happened. Caches of charred wheat at Westerwood (MacDonald 1934), for example, have no correlative in the on-site pollen record (see above). Imports to Roman forts in a range of foodstuffs have been explored (Dickson 1989; Dickson & Dickson 2000), and can be explored also in timber resources: at Rough Castle, hornbeam (*Carpinus*) and silver fir (*Abies*) were imported (Barber *in* Mate 1995); and at Cramond, wood for furniture from beech (*Fagus*), walnut (*Juglans*), pear (*Pyrus*) and lime (*Tilia*) came from outwith Scotland (Holmes 2003).

If crop-growing became less central to native farmers then stock-raising probably became more important. Whilst the bones of cattle, sheep/goat, pigs and wild animals were found at pre-Antonine native sites such as Fairy Knowe (Main 1998) and at Port Seton (Haselgrove & McCullagh 2000) – and this mix of species can be found at Roman civilian settlements (Thomas 1988; McCormick 2002) – cattle bones are dominant on Roman military sites (Bailey & Cannel 1996; McCormick 2002; Barnetson 2003). Although region-scale pollen records depict pasture more clearly than they will arable agriculture, the impression from local-scale records also supports the view of a landscape mostly given over to grazing (Dickson & Dickson 2000). It is tentatively possible from the apparent partial dereliction of the poorly drained soils of the Southern Plateaux in the late

Iron Age (see above) that this activity began to be focused on land nearer the Wall.

Nevertheless, it is likely that stock-raising was not intensively practiced, or was carefully managed. This can be implied from the near-absence of soil erosion, or accelerated geomorphic activity (see above), from the scarcity of plant species in pollen and charred plant assemblages indicative of overgrazing, from the persistence on soils even close to the Wall of poor grazing provided by *Calluna* heath (see above) and also from the absence of evidence for burning in region-scale pollen records (Ramsay & Dickson 1997): fire appears not to have been used to either clear the heath or to improve its quality for grazing animals. The demands of the Roman army, either through trade, exchange or taxation, were insufficient to force farmers to impose major stresses on the environment. Cattle populations may have been substantially higher than needed for native subsistence (see below) but were not excessively high. This was a landscape in some sort of balance. The invaders either did not need to extract too much from native farmers or thought that such an approach would be unrewarding. Native farmers in turn did not attempt to increase stocking densities beyond the capacity of soils.

How long was this balance maintained? Radiocarbon-dated pollen data at both region- and extralocal-scales on and near the Wall suggest that high levels of agricultural production did not persist after *c* cal AD 300 around Fannyside Muir, Glasgow Bridge, Letham Moss and Blairbech Bog (see above): Lenzie Moss now seems unusual in implying the maintenance of extensive agriculture long after Roman withdrawal (Ramsay 1995; Ramsay & Dickson 1997). Areas of farmland were lost to partial but substantial regeneration of woodland (Dumayne-Peaty 1998b; 1999; Dark 2000). The suggestion of declining agricultural productivity made by Boyd (1984a), albeit from insecurely stratified soil contexts, is supported by these new data. What might this pattern represent? It may represent the migration of the native population, but this is thought least likely. The interpretation of fluctuations in the proportions of farmland and woodland have too frequently been made in such simplistic terms (Tipping, 2004). The same pattern might more reasonably be that expected from a farming economy adjusting to changing market conditions by scaling down its activities, as has been suggested for the area around Hadrian's Wall (Dark & Dark 1996). The increased and inflated demands of the Roman army for locally raised beef ceased. Cattle populations were reduced and grazed land left to support woodland. Whether this is regarded as a decline (Dumayne 1993a; 1999) might depend on who was affected, but there is no reason to assume that this pattern represents population abandonment (cf Whittington & Edwards 1993; Dumayne-Peaty 1998b). This impression of the palaeoecological data – and it can only be that from the evidence to date – has a strong resonance with archaeological models that stress the economic damage done to native economies by Roman withdrawal (Macinnes 1984; Armit 1999) but in which native farmers, though less well off, persisted. Whether the native population in the region was smaller in *c* cal AD 300 than in *c* 100 cal BC is unclear but possible, but it takes fewer people to operate an overwhelmingly pastoral economy, as has sometimes been painfully learnt in this part of Scotland in the last several centuries (Devine 1994).

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REFERENCES

Armit, I 1999 'The abandonment of souterrains: evolution, catastrophe or dislocation?', *Proc Soc Antiq Scot* 129, 577–96.

Bailey, G B 1995a 'The Antonine frontier in Callander Park, Falkirk: its form and structural sequence', *Proc Soc Antiq Scot* 125, 577–600.

Bailey, G B 1995b 'Beancross', *in* Keppie L J F et al, 611–19.

Bailey, G B 1996 'Stream crossings on the Antonine Wall', *Proc Soc Antiq Scot* 126, 347–69.

Bailey, G B 1997 'Excavation of Roman, medieval and later features at Carriden Roman fort annexe in 1994', *Proc Society Antiq Scot* 127, 577–94.

Bailey, G B 2000 'Excavations on the Roman temporary camps at Three Bridges, Camelon, Falkirk', *Proc Soc Antiq Scot* 130, 469–89.

Bailey, G B & Cannel, J 1996 'Excavations at Kinniel fortlet and the Antonine Wall 1980–1', *Proc Soc Antiq Scot* 126, 303–46.

Barber, J 1985 'The pit alignment at Eskbank Nurseries', *Proc Prehist Soc* 51, 149–66.

Barber, J 1998 'Wooden posts', *in* Main, L, 301–2.

Barber, K E 1982 'Peat-bog stratigraphy as a proxy climatic record', *in* Harding, A F (ed) *Climatic Change in Later Prehistory*, 103–13. Edinburgh.

Barber, K E, Dumayne, L & Stoneman, R 1993 'Climatic change and human impact during the late Holocene in northern Britain', *in* Chambers, F M (ed) *Climate Change and Human Impact on the Landscape*, 225–36. London.

Barnetson, L 2003 'The human remains from the bath-house', *in* Holmes, N, 139–41.

Bibby, J S, Douglas, H A, Thomasson, A J & Robertson, J S 1982 *Land Capability Classification for Agriculture*. Aberdeen.

Birnie, J 1996 'Paleoenvironmental reports: pollen assessment', *in* Rideout, J, 242–7.

Bishop, M C (ed) 2002 *Roman Inveresk. Past, Present and Future*. Edinburgh.

Boardman, S & Dickson, C 1995 'Appendix 4: Analysis of botanical remains from Kirkintilloch', *in* Keppie, L J F et al, 666–8.

Boyd, W E 1984a 'Environmental change and Iron Age land management in the area of the Antonine Wall, central Scotland: a summary', *Glas Arch J* 11, 75–81.

Boyd, W E 1984b 'Prehistoric hedges: Roman Iron Age hedges from Bar Hill', *Scott Arch Rev* 3, 32–4.

Boyd, W E 1985a 'The problem of the time span represented by pollen spectra in podzol turves, with examples from the Roman sites at Bar Hill and Mollins, central Scotland', *in* Fieller, N R J, Gilbertson, D D & Ralph, N G A (eds) *Palaeobiological Investigations: Research Design, Methods and Data Analysis*, 189–201. Oxford.

Boyd, W E 1985b 'Palaeobotanical evidence from Mollins', *Britannia* 16, 37–48.

Boyd, W E 1986 'Vegetation history at Linwood Moss, Renfrewshire, central Scotland', *J Biogeography* 13, 207–23.

Boyd, W E 1988 'Cereals in Scottish antiquity', *Circaea* 5, 101–10.

Boyd, W E 1998 'Palaeobotanical remains', *in* Main, L, 310–16.

Breeze, D J 1974 'Excavations at the Roman fortlet on the Antonine Wall at Watling Lodge 1972–4', *Proc Soc Antiq Scot* 105, 166–75.

Breeze, D J 1979 *Roman Scotland. Some Recent Excavations*. Edinburgh.

Breeze, D J 1992 'The great myth of Caledon', *Scott Forum* 46, 331–5.

Breeze, D J 2004 *The Antonine Wall. The North-West Frontier of the Roman Empire*. Edinburgh.

Brown, A G 1997 *Alluvial Geoarchaeology*. Cambridge.

Brown, N 2001 *History and Climate Change. A Eurocentric Perspective*. London.

Buckland, P C & Edwards, K J 1984 'The longevity of pastoral episodes of clearance activity in pollen diagrams: the role of post-occupation grazing', *J Biogeography* 11, 243–9.

Bunting, M J 2003 'Pollen–vegetation relationships in non-arboreal moorland taxa', *Rev Palaeobot Palynol* 125, 285–98.

Cook, M 2004 'Howe Mire: excavations across the cropmark complex at Inveresk, Musselburgh', *Proc Soc Antiq Scot* 134, 131–60.

Crone, A 2000 *The History of a Scottish Lowland Crannog: Excavations at Buiston, Ayrshire, 1989–90*. Edinburgh.

Dark, K R & Dark, S P 1996 'New archaeological and palynological evidence for a sub-Roman reoccupation of Hadrian's Wall', *Arch Aeliana* 24, 57–72.

Dark, P 2000 *The Environment of Britain in the First Millennium AD*. London.

Davidson, D A & Carter, S P 1997 'Soils and their evolution', *in* Edwards, K J & Ralston, I B M (eds) *Scotland: Environment & Archaeology 8000 BC–AD 1000*, 45–62. Chichester.

Davidson, D A, Carter, S, Boag, B, Long, D, Tipping, R & Tyler, A 1999 'Analysis of pollen in soils: processes of incorporation and redistribution of pollen in five soil profile types', *Soil Biol Biochem* 31, 643–53.

Devine, T M 1994 *The Transformation of Rural Scotland: Social Change and the Agrarian Economy, 1660–1815*. Edinburgh.

Dickson, C 1981 'Appendix 3: Wood', *in* Keppie, L J F & Murray, J F, 258–9.

Dickson, C 1989 'The Roman army diet in Britain and Germany. *Diss Bot* 133, 135–54.

Dickson, C 1990 'Experimental processing and cooking of emmer and spelt wheats and the Roman army diet', *in* Robinson, D E (ed) *Experimentation and Reconstruction in Environmental Archaeology*, 33–9. Oxford.

Dickson, C & Dickson, J 1988 'The diet of the Roman army in deforested Scotland', *Plants Today* 1, 121–6.

Dickson, C & Dickson, J 2000 *Plants and People in Ancient Scotland*. Stroud.

Dickson, C, Dickson, J H & Breeze, D 1979 'Flour or bread in a Roman military ditch at Bearsden, Scotland', *Antiquity* 53, 437–42.

Dickson, J H 1980 'Carstairs area', *in* Jardine, W G (ed) *The Quaternary of the Glasgow Area*, 63–5. Glasgow.

Dickson, J H 1981 'A pollen diagram from the Auld Wives' Lifts, Craigmaddie Muir, Strathclyde', *Glas Arch J* 8, 13–18.

Dickson, J H 1988 'Post-glacial pine stumps in central Scotland', *Scott Forum* 42, 192–9.

Dickson, J H 1993 'Scottish woodlands: their ancient past and precarious present', *Scott Forum* 47, 73–8.

Dickson, J H, Jardine, W G & Price, R J 1976 'Three Late Devensian sites in west-central Scotland', *Nature* 262, 43–4.

Dickson, J H, Stewart, D A, Baxter, M, Drndarsky, N D, Thompson, R, Turner, G & Rose, J 1978 'Palynology, palaeomagnetism and radiometric dating of Flandrian marine and freshwater sediments of Loch Lomond', *Nature* 274, 548–53.

Dimbleby, G W & Sheldon, J 1978 'Appendix 4: Pollen, soils, charcoal and cereal grains', *in* Proudfoot, E V W, 125–7.

Dumayne, L 1992 *Late Holocene Palaeoecology and Human Impact on the Environment of Northern Britain*. Unpublished PhD Thesis, University of Southampton, Southampton.

Dumayne, L 1993a 'Invader or native? – vegetation clearance in northern Britain during Romano-British time', *Veget Hist Archaeobot* 1993, 29–36.

Dumayne, L 1993b 'Iron Age and Roman vegetation clearance in northern Britain: further evidence', *Bot J Scot* 46, 385–92.

Dumayne, L 1994 'The effect of Roman occupation on the environment of northern Britain: pollen data from Fozy Moss, Northumbria', *Britannia* 25, 217–24.

Dumayne, L 1995 'Human impact on vegetation in northern Cumbria since the Bronze Age: relating palynological and archaeological evidence', *Trans Cumb West Antiq Arch Soc* 95, 23–33.

Dumayne, L & Barber, K E 1994 'The impact of the Romans on the environment of northern England: pollen data from three sites close to Hadrian's Wall', *The Holocene* 4, 165–73.

Dumayne, L, Stoneman, R, Barber, K & Harkness, D 1995 'Problems associated with correlating calibrated radiocarbon-dated pollen diagrams with historical events', *The Holocene* 5, 118–23.

Dumayne-Peaty, L 1998a 'Forest clearance in northern Britain during Romano-British times: re-addressing the palynological evidence', *Britannia* 26, 315–22.

Dumayne-Peaty, L 1998b 'Human impact on the environment during the Iron Age and Romano-British times: palynological evidence from three sites near the Antonine Wall', *J Arch Sci* 25, 203–14.

Dumayne-Peaty, L 1999 'Continuity or discontinuity? Vegetation change in the Hadrianic–Antonine frontier zone of northern Britain at the end of the Roman occupation', *J Biogeography* 26, 643–65.

Dumayne-Peaty, L & Barber, K E 1998 'Late Holocene vegetation history, human impact and pollen representivity variations in northern Cumbria, England', *J Quaternary Sci* 13, 147–64.

Dunwell, A 1995 ‘Carriden’, *in* Keppie, L J F et al, 602–6.

Dunwell, A & Coles, G 1998 ‘Archaeological and palynological investigations on the Antonine Wall, near Glasgow Bridge, Kirkintilloch’, *Proc Soc Antiq Scot* 128, 461–79.

Dunwell, A & Ralston, I 1995 ‘Excavations at Inveravon on the Antonine Wall 1991’, *Proc Soc Antiq Scot* 125, 521–76.

Dunwell, A, Bailey, G, Leslie, A & Smith, A 2002 ‘Some excavations on the line of the Antonine Wall, 1994–2001’, *Proc Soc Antiq Scot* 132, 259–304.

Durno, S E 1965 ‘Pollen analytical evidence of “landnam” from two Scottish sites’, *Trans Bot Soc Edin* 40, 13–19.

Edwards, K J 1979 ‘Palynological and temporal inference in the context of prehistory, with special reference to the evidence from lake and peat deposits’, *J Arch Sci* 6, 255–70.

Edwards, K J 1982 ‘Man, space and the woodland edge – speculations on the detection and interpretation of human impacts in pollen profiles’, *in* Bell, M & Limbrey, S (eds) *Archaeological Aspects of Woodland Ecology*, 5–22. Oxford.

Edwards, K J & Whittington, G 2001 ‘Lake sediments, erosion and landscape change during the Holocene in Britain and Ireland’, *Catena* 42, 143–73.

Ellis, C & Gooder, J W 2002 ‘Shirva, East Dunbartonshire: Evaluation 3’, *in* Dunwell, A et al, 273–4.

Erdtman, G 1928 ‘Studies in the post-arctic history of the forests of north-western Europe. I. Investigations in the British Isles’, *Geol Fören Stockh Förh* 50, 123–92.

Eydt, H 1958 ‘A pollen diagram from a blanket bog in the Campsie Fells’, *Trans Bot Soc Edin* 39, 28–34.

Fraser, G K & Godwin, H 1955 ‘Two Scottish pollen diagrams: Carnwath Moss, Lanarkshire, and Strichen Moss, Aberdeenshire’, *New Phytol* 54, 216–21.

Frere, S S & Wilkes, J 1989 *Strageath: Excavations Within the Roman Fort 1973–86*. London.

van Geel, B, Buurman, J & Waterbolk, H T 1996 ‘Archaeological and palaeoecological indications of an abrupt climate change in The Netherlands, and evidence for climatological teleconnections around 2650 BP’, *J Quaternary Sci* 11, 451–60.

Glendinning, B & Cameron, K 2002 ‘Shirva, East Dunbartonshire: Evaluations 1 & 2’, *in* Dunwell, A et al, 273.

Grieve, I C 1993 ‘Soils’, *in* Corbett, L & Dix, N J (eds) *Central Scotland: Land–Wildlife–People*, 32–42. Stirling.

Hale, A 2000 ‘Marine crannogs: previous work and recent surveys’, *Proc Soc Antiq Scot* 130, 537–58.

Hale, A 2003 ‘Seeing the unseen: locating marine crannogs’, *in* Dawson, T (ed) *Coastal Archaeology and Erosion in Scotland*, 155–62. Edinburgh.

Hamilton, J, Clarke, C, Dunwell, A & Tipping, R 2002 ‘A prehistoric ford near Rough Castle, Falkirk’, *Scott Arch J* 23, 91–103.

Hanson, W S 1978 ‘The organisation of the Roman military timber supply’, *Britannia* 9, 293–305.

Hanson, W S 1979 ‘Croy Hill’, *in* Breeze, D.

Hanson, W S 1996 ‘Forest clearance and the Roman army’, *Britannia* 27, 354–8.

Hanson, W S 1997 ‘The Roman presence: brief interludes’, *in* Edwards, K J & Ralston, I B M (eds) *Scotland: Environment & Archaeology 8000 BC–AD 1000*, 195–216. Chichester.

Hanson, W S & MacInnes, L 1980 ‘Forests, forts and fields: a discussion’, *Scott Arch Forum* 12, 98–113.

Hanson, W S & Maxwell, G S 1983a *Rome’s North West Frontier: the Antonine Wall*. Edinburgh.

Hanson, W S & Maxwell, G S 1983b ‘Minor enclosures on the Antonine Wall at Wilderness Plantation’, *Britannia* 14, 227–43.

Haselgrove, C & McCullagh, R 2000 *An Iron Age Coastal Community in East Lothian: The Excavation of Two Later Prehistoric Enclosure Complexes at Fisher’s Road, Port Seton, 1994–5*. Edinburgh.

Hastie, M 2002 ‘Auchendavy, East Dunbartonshire’, *in* Dunwell, A et al, 274–6.

Holloway, L K 2002 *Sedimentary Environments in the Western Forth Valley during the Late Devensian and Early Holocene*. Unpublished PhD Thesis, University of Coventry, Coventry.

Holmes, N 2003 *Excavation of Roman Sites at Cramond, Edinburgh*. Edinburgh.

Hunter, F & Collard, M ‘The Cramond lioness’, *Curr Arch* 155, 404–7.

Huntley, J P 2000 ‘Late Roman transition in the north: the palynological evidence’, *in* Wilmott, T & Wilson, P (eds) *The Late Roman Transition in the North*, 67–71. Oxford.

Jacobson, G L Jr & Bradshaw, R H W 1981 'The selection of sites for paleovegetational studies', *Quaternary Res* 16, 80–96.

James, H 2003 'Assessment survey: the Firth of Forth (Dunbar to the border of Fife)', *in* Dawson, T (ed) *Coastal Archaeology and Erosion in Scotland*, 119–26. Edinburgh.

Johnston, R 2002 '"Breaking new ground": land tenure and fieldstone clearance during the Bronze Age', *in* Bruck, J (ed) *Bronze Age Landscapes. Tradition and Transformation*, 99–108. Oxford.

Jones, M E 1996 *The End of Roman Britain*. London.

Keppie, L J F 1974 'The building of the Antonine Wall: archaeological and epigraphic evidence', *Proc Soc Antiq Scot* 105, 151–65.

Keppie, L J F 1979 'Some rescue excavations on the line of the Antonine Wall, 1973–6', *Proc Soc Antiq Scot* 109, 61–80.

Keppie, L J F 1994–5 'A Roman camp gateway at Castledykes', *Glas Arch J* 19, 75–81.

Keppie, L J F & Breeze, D J 1981 'Some excavations on the line of the Antonine Wall 1957–80', *Proc Soc Antiq Scot* 111, 229–47.

Keppie, L J F & Murray, J F 1981 'A Roman hypocausted building at Falkirk', *Proc Soc Antiq Scot* 111, 248–62.

Keppie, L J F & Walker, J J 1989 'Some excavations along the line of the Antonine Wall, 1981–5', *Proc Soc Antiq Scot* 119, 143–59.

Keppie, L J F, Bailey, G B, Dunwell, A J, McBrien, J H & Speller, K 1995 'Some excavations on the line of the Antonine Wall 1985–93', *Proc Soc Antiq Scot* 125, 601–71.

Keppie, L J F, Fitzpatrick, A, Walker, J J, Webster, P V, Young, A & Tipping, R 1994–5 'Excavations on the Roman fort at Westerwood on the Antonine Wall, 1985–8', *Glas Arch J* 19, 83–99.

Knights, B A, Dickson, C A, Dickson, J H & Breeze, D J 1983 'Evidence concerning the Roman military diet at Bearsden, Scotland, in the second century AD', *J Arch Sci* 10, 139–52.

Lamb, H H 1981 'Climate from 1000 BC to 1000 AD', *in* Jones, M & Dimbleby, G W (eds) *The Environment of Man: the Iron Age to the Anglo–Saxon Period*, 53–65. Oxford.

Lamb, H H 1982 *Climate, History and the Modern World*. London.

Langdon, P G & Barber, K E 2004 'Snapshots in time: precise correlations of peat-based proxy climate records in Scotland using mid-Holocene tephras', *The Holocene* 14, 21–34.

Langdon, P G, Barber, K E & Hughes, P D M 2003 'A 7500-year peat-based palaeoclimatic reconstruction and evidence for an 1100-year cyclicity in bog surface wetness from Temple Hill Moss, Pentland Hills, SE Scotland', *Quaternary Sci Rev* 22, 259–74.

Long, D J, Tipping, R, Carter, S, Davidson, D A, Boag, B & Tyler, A 2000 'The replication of pollen stratigraphies in soil pollen profiles: a test', *in* Harley, M M, Morton, C M & Blackmore, S (eds) *Pollen and Spores: Morphology and Biology*, 481–97. Kew.

McCarthy, M 1995 'Archaeological evidence for the Roman impact on vegetation near Carlisle', *The Holocene* 5, 491–5.

McCormick, M 2002 *in* Bishop, M C.

MacDonald, G 1924 'Discoveries on the line of the Antonine Wall', *Proc Soc Antiq Scot* 46, 270–95.

MacDonald, G 1934 *The Roman Wall in Scotland*. Oxford.

MacDonald, G & Park, A 1905 'The Roman forts on the Bar Hill, Dumbartonshire', *Proc Soc Antiq Scot* 40, 403–546.

MacInnes, L 1984 'Brochs and the Roman occupation of lowland Scotland', *Proc Soc Antiq Scot* 114, 235–49.

MacIvor, I, Thomas, M C & Breeze, D J 1980 'Excavations on the Antonine Wall fort of Rough Castle, Stirlingshire 1957–61', *Proc Soc Antiq Scot* 110, 230–85.

Macklin, M G 1999 'Holocene river environments in prehistoric Britain: human interaction and impact', *in* Edwards, K J & Sadler, J P (eds) *Holocene Environments of Prehistoric Britain*, 521–30. Chichester.

Macklin, M G & Lewin, J 2003 'River sediments, great floods and centennial-scale Holocene climate change', *J Quaternary Sci*, 18, 101–6.

Main, L 1998 'Excavation of timber round-house and broch at the Fairy Knowe, Buchlyvie, Stirlingshire, 1975–8', *Proc Soc Antiq Scot* 128, 293–418.

Mate, I D 1995 'Excavations of an enclosure system at Rough Castle, Falkirk', *Proc Soc Antiq Scot* 125, 483–97.

Maxwell, G S 1989 *The Romans in Scotland*. Edinburgh.

Maxwell, G S & Wilson, D R 1987 'Air reconnaissance in Roman Britain, 1977–84', *Britannia* 18, 1–48.

Mercer, R & Tipping, R 1994 'The prehistory of soil erosion in the northern and eastern Cheviot Hills, Anglo-Scottish Borders', *in* Foster, S & Smout, T C (eds) *The History of Soils and Field Systems*, 1–24. Aberdeen.

Miles, J 1985 'The pedogenetic effects of different species and vegetation types and the implications of succession', *J Soil Sci* 36, 571–84.

Miller et al 2000 *in* Haselgrove, C & McCullagh, R *An Iron Age Coastal Community in East Lothian: The Excavation of Two Later Prehistoric Enclosure Complexes at Fisher's Road, Port Seton, 1994–5*. Edinburgh.

Mills, C 2000 'Palynological analysis', *in* Crone, A, 68–9.

Mowat, R J C 1996 *The Logboats of Scotland*. Oxford.

Newell, P 1983 *in* Hanson, W S & Maxwell, G S 1983b 'Minor enclosures on the Antonine Wall at Wilderness Plantation', *Britannia* 14, 227–43.

Newey, W W 1967 'Pollen analyses from south-east Scotland', *Trans Bot Soc Edin* 40, 424–34.

Oliver, M A, Webster, R, Edwards, K J & Whittington, G 1997 'Multivariate, autocorrelation and spectral analyses of a pollen profile from Scotland and evidence for periodicity', *Rev Palaeobot Palynol* 96, 121–44.

Parkyn, L, Stoneman, R & Ingram, H A P 1997 *Conserving Peatlands*. Oxford.

Paul, M, Peacock, J D & Barras, B F 1995 'Flandrian stratigraphy and sedimentation in the Bothkennar–Grangemouth area, Scotland', *Quaternary Newsletter* 75, 22–35.

Pennington, W 1979 'The origin of pollen in lake sediments: an enclosed lake compared with one receiving inflow streams', *New Phytol* 83, 189–213.

Potter, T W 1976 'Valleys and settlement: some new evidence', *World Archaeology* 8, 207–19.

Potter, T W 1979 *Romans in North West England: Excavations at the Roman Forts of Ravenglass, Watercrook and Bowness on Solway*. Kendal.

Proudfoot, E V W 1978 'Camelon native site', *Proc Soc Antiq Scot* 109, 112–28.

Raisin, P 2003 'Insect remains', *in* Holmes, N, 136–7.

Ramsay, S 1995 *Woodland Clearance in West-central Scotland during the Past 3000 Years*. Unpublished PhD Thesis, Glasgow University, Glasgow.

Ramsay, S 1996 'Human impact on the vegetation around Walls Hill', *in* Alexander, D (ed) *Prehistoric Renfrewshire*, 59–63. Paisley.

Ramsay, S 2000 'Appendix 1: Pollen analysis from Huntingtower', *in* Woolliscroft, D J, 505–7.

Ramsay, S & Dickson, J H 1997 'Vegetation history of central Scotland', *Bot J Scot* 49, 141–50.

Rideout, J 1996 'Excavation of a promontory fort and a palisaded homestead at Lower Greenyards, Bannockburn, Stirling, 1982–5', *Proc Soc Antiq Scot* 126, 199–269.

Riddell, J 1979 *Clyde Navigation: a History of the Development and Deepening of the River Clyde*. Edinburgh.

Robinson, M 1993 'Microfossil analyses and radiocarbon dating of depositional sequences related to Holocene sea-level change in the Forth Valley, Scotland', *Trans Roy Soc Edin: Earth Sci* 84, 1–60.

Romans, J C C & Robertson, L 1983 'The environment of north Britain: soils', *in* Chapman, J C & Mytum, H C (eds) *Settlement in North Britain 1000 BC–AD 1000*, 55–67. Oxford.

Rose, J 1975 'Raised beach gravels and ice wedge casts at Old Kilpatrick, near Glasgow', *Scott J Geol* 11, 15–21.

Rose, J 2003 'Geilston: Lateglacial and Holocene sea-level change', *in* Evans, D J A (ed) *The Quaternary of the Western Highland Boundary: Field Guide*, 190–9. London.

Shennan, I & Horton, B 2002 'Holocene land and sea-level changes in Great Britain', *J Quaternary Sci* 17, 511–27.

Shotter, D 1996 *The Roman Frontiers in Britain*. Preston.

Sissons, J B 1972 'Dislocation and non-uniform uplift of raised shorelines in the western part of the Forth valley', *Trans Inst Br Geogr*, 55, 145–59.

Sissons, J B 1976 *The Geomorphology of the British Isles: Scotland*. London.

Smith, D E 1968 'Postglacial displaced shorelines in the surface of the carse clay on the north bank of the river Forth, in Scotland', *Zeit Geomorph* 12, 388–408.

Smith, D E, Cullingford, R A & Firth, C R 2000 'Patterns of isostatic land uplift during the Holocene: evidence from mainland Scotland', *The Holocene* 10, 489–501.

Stewart, D E 1983 'The history of alder, *Alnus glutinosa* (L) Gaertn, in the Campsie Fells', *Glasgow Nat* 20, 333–45.

Stewart, D E, Walker, A & Dickson, J H 1984 'Pollen diagrams from Dubh Lochan, near Loch Lomond', *New Phytol* 98, 531–49.

Stoneman, R 1993 *Holocene Palaeoclimates from Peat Stratigraphy: Extending and Refining the Model*. Unpublished PhD Thesis, Southampton University, Southampton.

Strang, A 1998 'Recreating a possible Flavian map of Roman Britain, with a detailed map for Scotland', *Proc Soc Antiq Scot* 128, 425–40.

Thomas, G D 1988 'Excavations at the Roman civil settlement at Inveresk', *Proc Soc Antiq Scot* 118, 139–76.

Tipping, R 1992 'The determination of cause in the generation of major prehistoric valley fills in the Cheviot Hills, Anglo-Scottish Border', *in* Needham, S & Macklin, M G (eds) *Alluvial Archaeology in Britain*, 111–21. Oxford.

Tipping, R 1994 'The form and fate of Scottish woodlands', *Proc Soc Antiq Scot* 124, 1–54.

Tipping, R 1994–5 *in* Keppie, L J F, Fitzpatrick, A, Walker, J J, Webster, P V, Young, A & Tipping, R 1994–5 'Excavations on the Roman fort at Westerwood on the Antonine Wall, 1985–8', *Glas Arch J* 19, 83–99.

Tipping, R 1995a 'Holocene evolution of a lowland Scottish landscape: Kirkpatrick Fleming. III. Fluvial history', *The Holocene* 5, 184–95.

Tipping, R 1995b 'Appendix 4: Analysis of rampart material at Tayavalla', *in* Keppie, L J F et al 1995, 666.

Tipping, R 1997a 'Environment and environmental change in Eastern Dumfriesshire', *in* RCAHMS *Eastern Dumfriesshire. An Archaeological Landscape*, 10–25. Edinburgh.

Tipping, R 1997b 'Pollen analysis, late Iron Age and Roman agriculture around Hadrian's Wall', *in* Gwilt, A & Haselgrove, C (eds) *Reconstructing Iron Age Societies*, 239–47. Oxford.

Tipping, R 2002a 'Living in the past: woods and people in prehistory to 1000 BC', *in* Smout, T C (ed) *People and Woods in Scotland: A History*, 14–39. Edinburgh.

Tipping, R 2002b 'Climatic variability and 'marginal' settlement in upland British landscapes: a re-evaluation', *Landscapes* 3, 10–28.

Tipping, R 2004 'Palaeoecology and political history: evaluating driving forces in historic landscape change in southern Scotland', *in* Whyte, I & Winchester, A J L (eds) *Society, Landscape and Environment in Upland Britain*, 11–21. Birmingham.

Tipping, R, Carter, S & Johnston, D 1994 'Soil pollen and soil micromorphological analyses of old ground surfaces on Biggar Common, Borders Region, Scotland', *J Arch Sci* 21, 387–401.

Tipping, R, Long, D, Carter, S, Davidson, D A, Tyler, A & Boag, B 1999a 'Testing the potential of soil-stratigraphic palynology in podsols', *in* Pollard, A M (ed) *Geoarchaeology: Exploration, Environments, Resources*, 79–90. London.

Tipping, R, Milburn, P & Halliday, S 1999b 'Fluvial processes, land use and climate change 2000 years ago in upper Annandale, southern Scotland', *in* Brown, A G & Quine, T (eds) *Fluvial Processes and Environmental Change*, 311–28. Chichester.

Tipping, R, Thompson, R & Young, R 2000 'The sedimentary history of Buiston Loch', *in* Crone, A, 36–47.

Turner, J 1965 'A contribution to the history of forest clearance', *Proc Roy Soc Lond* B161, 343–54.

Turner, J 1970 'Post-Neolithic disturbance of British Vegetation', *in* Walker, D & West, R G (eds) *Studies in the Vegetational History of the British Isles*, 97–116. Cambridge.

Turner, J 1975 'The evidence for land use by prehistoric farming communities: the use of three-dimensional pollen diagrams', *in* Evans, J G, Limbrey, S & Cleere, H (eds) *The Effect of Man on the Landscape: the Highland Zone*, 86–95. London.

Turner, J 1979 'The environment of north east England during Roman times as shown by pollen analysis', *J Arch Sci* 6, 285–90.

Turner, J 1981 'The Iron Age', *in* Simmons, I G & Tooley, M J (eds) *The Environment in British Prehistory*', 250–81. London.

Turner, J 1983 'Some pollen evidence for the environment of northern Britain 1000 BC to AD 1000', *in* Chapman, J C & Mytum, H C (eds) *Settlement in North Britain 1000 BC–AD 1000*, 3–27. Oxford (=Br Archaeol Rep, Br Ser 118).

van der Veen, M 1992 *Crop Husbandry Regimes – An Archaeological Study of Farming in Northern England 1000 BC–AD 500*. Sheffield.

Whittington, G & Edwards, K J 1993 '*Ubi solitudinem faciunt pacem appellant*: the Romans in Scotland, a palaeoenvironmental contribution', *Britannia* 24, 13–25.

Whittington, G, Edwards, K J & Caseldine, C J 1991 'Late- and post-glacial pollen-analytical and environmental data from a near-coastal site in north-east Fife, Scotland', *Rev Palaeobot Palynol* 68, 65–85.

Whittington, G, Edwards, K J & Cundill, P R 1990 *Palaeoenvironmental Investigations at Black Loch, in the Ochil Hills of Fife, Scotland*. Aberdeen.

Whittow, J B 1977 *Geology and Scenery in Scotland*. London.

Whyte, I D 1979 *Agriculture and Society in 17th-Century Scotland*. Edinburgh.

Wilkes, J J 1981 'Tollparks', *in* Keppie, L J F & Breeze, D J, 231.

Wilmott, T 2003 'Aspects of recent archaeology on Hadrian's Wall', *in* Frodsham, P (ed) *Archaeology in Northumberland National Park*, 224–35. York.

Wood, J S 1989 'Castra Cottage, Castlecary', *in* Keppie, L J F & Walker, J J, 150.

Woolliscroft, D J 2000 'The Roman Gask series tower at Westmains of Huntingtower, Perth and Kinross', *Proc Soc Antiq Scot* 130, 491–507.

Woolliscroft, D J 2002 *The Roman Frontier on the Gask Ridge, Perth and Kinross. An Interim Report on the Roman Gask Project 1995–2000.* Oxford.