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Ancient Monuments Laboratory
Report 42/93

ANTHROPOGENIC MODIFICATION OF THE EARLY HOLOCENE SOIL ENVIRONMENT

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Summary

The human impact on early Holocene soils is discussed with reference to four major processes - podzolisation, peat formation, particle translocation and valley sedimentation. The difficulty of distinguishing natural from anthropogenic features is emphasised. The Neolithic to Iron Age period is identified as a major phase of soil alteration, but its importance must be set against the data bias inherent in earthwork-based studies and the likely availability of systems already nearing their Catastrophe-thresholds by Neolithic times.

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Anthropogenic Modification of the early Holocene Soil Environment.

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(first published in SEESOIL, the Journal of the
South-East England Soils Discussion Group, 8.)

Introduction

Holocene soil formation has been characterised by a substantial impact from human activities, alongside a 'natural' background of factors such as parent material, climate and vegetation. At the beginning of the period the North Sea was dry and Britain was still joined to the continent. Forests of birch and pine were gradually replacing the Northern European tundra followed, as warming proceeded, by hazel. Sea-level rose rapidly around 8ka - 6ka BP isolating the British Isles and ushering in the climatic optimum of relatively warm oceanic conditions favouring forests of oak, elm, alder and lime (Pennington 1974). Evidence for subsequent climatic deterioration through the Bronze Age and Iron Age has to be extricated from a palaeo-ecological record containing evidence for clearance and agricultural activities.

The anthropogenic component of Holocene pedogenesis must be partly a function of population, and it is worth examining the types of numbers involved. The English Mesolithic and Neolithic populations have been estimated as around 10 to 100 thousand (Fowler 1978) building to about 0.25 - 1 million by the end of the Bronze Age. Taylor (in Hoskins 1988) described a slightly earlier increase to about 1 million during the early Bronze Age. Thereafter, there seems to have been a steady rise to at least 2 million in the Roman period. The effect that these people had on their soils will now be examined in the light of four major processes, namely - podzolisation, peat development, particle translocation and valley sedimentation.

Podzolisation

There is a large body of evidence supporting the view that podzolisation, although a natural process, is strongly influenced by human activity. It has been understood for many years that the translocation of iron, aluminium and humus complexes is initiated naturally in some places (Mackney 1961; Matthews 1980). This is often associated with invasion by acidophile species after leaching of the cations (chiefly calcium) has brought conditions to an acidity threshold. The speed with which the leaching proceeds is inversely correlated with the soil buffer capacity. This accounts, at least in part, for the occurrence of podzols only on clay-poor parent materials (Petersen 1976). The importance of deciduous forest cover in maintaining nutrient cycling is critical on substrates with the light textures and surplus moisture regimes suitable for podzol development. However, given enough time, even well-wooded soils with these characteristics must eventually tend to podzolise, unless there are fresh cation inputs to the system.

Anthropogenic activity which depletes the cation reserve serves to hasten the process along. Clearance results in base depletion, either by physical removal of the wood, or by mobilising some of the nutrient reserve as the soluble constituents of woodash. If clearance is followed by agriculture, the net effect is likely to be cation depletion. This can be brought about both by removal of the food products, and by the lower nutrient circulation efficiency of shallow rooted crop plants. Subsequent abandonment will allow the invasion of heathers, promoting the formation of mor humus and further reducing the nutrient cycling capability of the system (Avery 1990).

The speed of podzolisation seems to be very variable. Andersen (1979) reported podzols developing in 250 years, whereas authors such as Tamm (1950) and Perrin et al. (1964) put the figure at between 1000 and 3000 years. Some of these differences may be due to different types of podzol being dated; for example, Crompton (1952) reported thin iron pans developing in as little as 100 years. Nevertheless, the overall range of the values argues for a non-specific view of the horizon differentiation rate. Such a view is intuitively suited to the types of variables involved in the podzolisation equation; for example, variations of mineralogical composition or particle size distribution will play a large part in determining the exact rate at which different soils acidify and podzolise. If other factors remain constant, a mosaic of reasonably coarse parent materials would therefore be expected to produce a variety of podzolisation dates, as has now been demonstrated in the New Forest (Reynolds and Catt 1987).

The evidence for podzolisation dates is provided mainly by archaeological sites, usually where earthworks have buried the old landsurface and halted or severely reduced its pedological development. Isolated cases of acidification have been reported from the Mesolithic (Keef et al. 1965) and Neolithic (Macphail 1990a) but, although podzolisation has been recorded under some Neolithic barrows in Holland (Runia 1988; Waterbolk 1957), the wealth of evidence points to the late Neolithic and Bronze Age as the major period of transition from brown-earth to podzol. Dimbleby (1957, 1962, 1965) found brown earths, leached brown earths and podzols under a range of Bronze Age barrows in North Yorkshire, Hampshire, Dorset and Kent. Cornwall (1953, 1955, 1962) found similar evidence in Dorset, Derby and Leicestershire. Keeley and Macphail (1979) could find only slight evidence for post-Bronze age changes in an upland catena of podzols, brown podzolics and stagnopodzols on Dartmoor. More recently, podzols buried under Bronze Age earthworks have been described by Macphail (1981, 1988). It should be noted that these pedological cases are inevitably skewed towards the Bronze Age because of the large number of surviving earthworks; earlier examples of podzol development would not be recorded to the same extent due to lack of sites. Furthermore, the earthwork locations may well be non-random both in terms of exposure and pre-construction soil conditions (Limbrey 1975). The deliberate siting of earthworks on agriculturally low-value soils and/or exposed sites would tend to exaggerate the apparent advancement of podzolisation at the time of construction. However, the pollen analytical evidence, often from a longer term record (e.g. Chambers et al. 1986), suggests a good correlation between clearance (typically from the Neolithic onwards) and the rise of heathland at around the same time.

If clearance had not occurred, many of today's podzols might still be some form of brown soil; in this respect, they can be termed "anthropogenic". In other cases, particularly where the parent material was low in base-rich minerals, podzolisation would have proceeded rapidly at the beginning of the Holocene, without any human initiation. The dynamics of the forest system under which brown soils were maintained produced a delicate homeostasis which, like modern tropical systems, was liable to substantial change after brief destructional interference.

Upland peat development

The initiation and development of upland peat is allied closely to the podzolisation issues discussed above. Ball (1983) described leaching, acidity, podzolisation and peat formation as one soil forming "direction" in the highland areas.

On Dartmoor, Simmons (1969) found evidence for the initiation of blanket bog in the Mesolithic, but the main development occurred during the Neolithic and Bronze Age associated with clearance and settlement around 4400-3400 BP. Areas of peat deeper than about 60cm were all initiated by the Iron Age. Similar conditions of occupation and reduced forest cover were reported by Spratt and Simmons (1976) on the North York Moors. In the southern Pennines (Jacobi et al. 1976) and Cleveland (Jones 1976), blanket peat appears to have initiated earlier, during the Mesolithic.

Peat initiation may have been caused by tree-clearance reducing transpiration and allowing waterlogging (Moore 1975). The use of fire as a management tool (Simmons and Innes 1987; Jacobi et al. 1976) has also been invoked as a reason for the failure of the forest to regenerate. Parallels with the podzolisation processes are evident here, since acidification would reduce earthworm activity and promote iron-pan development both of which could radically alter the drainage conditions. This type of cross-over from a (broadly) podzolising soil environment to one encouraging peat growth is summarised in Figure 1. Charman (1992) has recently stressed the importance of localised factors such as drainage in determining the onset of peat growth, showing that a wide range of dates were applicable to some Scottish sites and that no single factor could be considered causative. Evidence of burning could be found as far back as 9100 BP and successive events had affected the tree-cover in various ways. McHugh (1992) found large discrepancies on adjacent sites in the Northern Pennines, with woodland persisting on slopes and the peat accumulating on plateaux. As with podzolisation, it is important to distinguish causation from acceleration and to emphasise the variety of site - specific details that underlie the broad generalities of the development process.

POTENTIAL PATHWAYS OF SOIL EVOLUTION IN THE BRITISH UPLANDS

The rate of soil evolution will be faster in areas of higher rainfall though any stage of development can be meta-stable under appropriate combinations of environmental factors. Evolutionary pathways may be influenced and accelerated by forest clearance.

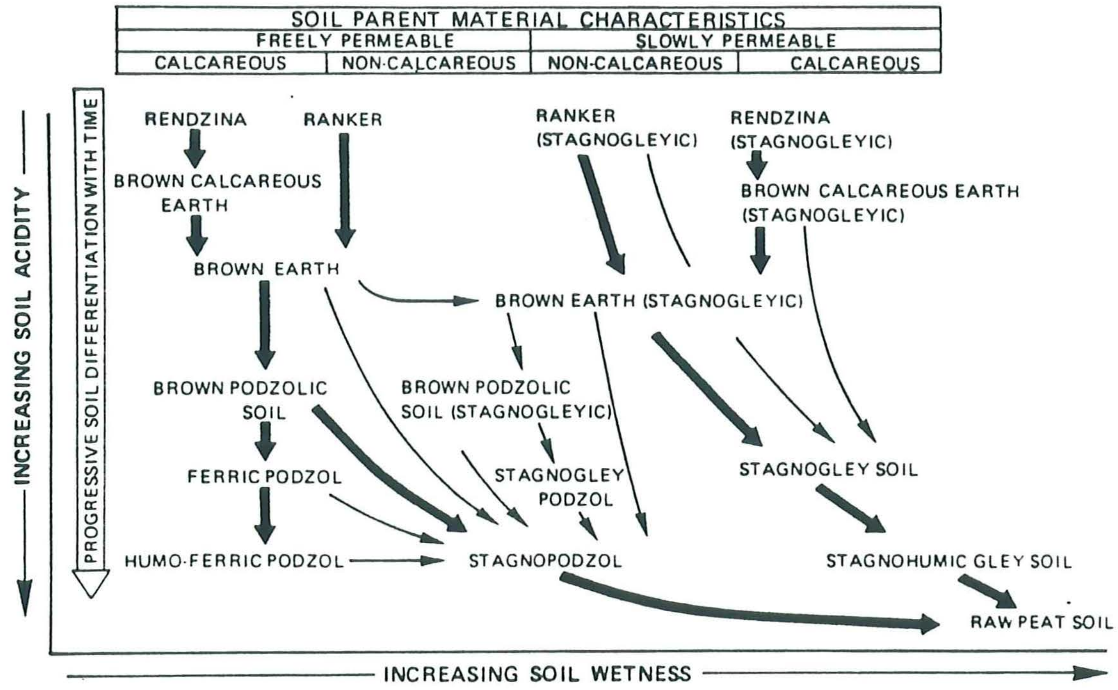

Figure 1 (from Askew et al. 1985)

Particle translocation

The growth of micromorphology as a tool in the study of Holocene soil history has led to a burgeoning of studies involving inferences based on particle translocation. The role that humans have played in these movements is extremely significant in archaeological studies because of the potential for recording sequential change under varied landuse or natural regimes. The formation of horizons of illuvial clay has been dated as pre-Neolithic (presumably under forest) in a few places (Weir et al. 1971; Valentine and Dalrymple 1975; MacPhail 1990b; French 1988) and slightly later at some north European sites (Langohr and Van Vliet 1979; Kwaad and Mucher 1977). More recent dateable examples are rare, but Fisher (1983) was able to date an illuvial horizon as post-Bronze Age in Wiltshire. The translocation and deposition processes appear to be fairly straightforward, in that coatings can be reproduced in laboratory experiments with as little as 100 clay/water applications to a suitably porous substrate (Dalrymple and Theocharopoulos 1984). However, their actual occurrence in soils seems to involve a number of physico-chemical prerequisites such as suitable void distribution, low Ca, Mg, Al and a pH range of 4.5 - 6.5 (McKeague 1983). The low calcium status in particular has been widely accepted as essential despite cases of coatings forming in calcareous soils (Aguilar et al. 1983). Pronounced wetting and drying cycles promote both the translocation and deposition of the clay, and the significance of factors such as low bioturbation and mineralogical composition have also been stressed by some authors (Van Ranst et al. 1983; Langohr and Van Vliet 1979). In the context of these finely tuned factor interactions, the human impact on clay translocation is harder to define than with the other major processes. Limbrey (1975) has invoked the cation loss and exposure to drying attendant on clearance by Neolithic people as an accelerating factor; Smith (1975) found accelerated clay translocation on soils in the vicinity of a Romano-British earthwork and ascribed it to cultivation; Romans and Robertson (1983) found that much of the clay in the Bt horizon under a Scottish Bronze Age mound had accumulated since its construction; Slager and Van de Wetering (1977) suggested that the presence of potash had increased the rate of translocation in some German archaeological pits relative to local loessial soils.

Recent interest has focussed on the translocation of impure clays, silts and even sand particles from upper to lower horizons. Illuvial silt, clay and humus were defined as characteristic of an Agric horizon (Soil Survey Staff 1975) occurring as a compact zone below cultivated topsoils. A detailed classification of the micromorphological features in similar layers was attempted by Jongerius (1970) and used by Kwaad and Mucher (1979) to infer human cultivation episodes. The occurrence of pores lined first with limpid clay coatings and then with coarser materials suggested forest clearance to Slager and Van der Wetering (1977), who described the impact of raindrops on bare soil as a "sine qua non" for the mobilisation of the coarse clay and fine silt.

Most authors point out that these interpretations are necessarily tentative, and perhaps natural processes cannot always be ruled out. It is possible, in some cases, for the structural breakdown of the eluvial horizon to be a function of its clay-loss (Payton 1980; Limbrey 1978), potentially making the coarsening-inwards of some types of coatings automatic. Surface cracking can provide the means for inwashing of topsoil materials as described by Jongerius (1970) for the Knip soils of the Netherlands, and under some circumstances, this could generate "pseudo-agricutans". There must also be disturbance effects associated with soil moving wild animals such as moles and wild boar. At the current stage of research, the use of particle translocations as indicators of human activity needs confirmatory archaeological evidence (Courty et al.1989).

Valley sedimentation

The extent of human influence on alluvial and colluvial valley fills again reflects a complex of anthropogenic and natural processes which are not easily disentangled. However, the evidence for these processes has the advantage that the changed sedimentary regimes attendant on human activity have frequently built on, rather than obliterated, their predecessor's deposits.

Bell (1982) argued that the British alluvial sequence is fundamentally similar across a range of valleys. The lower sediments are fine-textured, rich in organic material and often highly reduced.

They contain occasional mineral bands due to particular episodes of increased erosion, but are normally indicative of a slow, stable sedimentation rate occurring chiefly in wooded catchments. Above these layers are coarser, high mineral/low organic, oxidised sediments deposited as the result of accelerated erosion after forest clearance. His assemblage of initiation dates for these upper layers pointed to a time-band from the Bronze Age through to Romano-British times, with further thicknesses accreting in the historical period as a result of larger scale forest destruction.

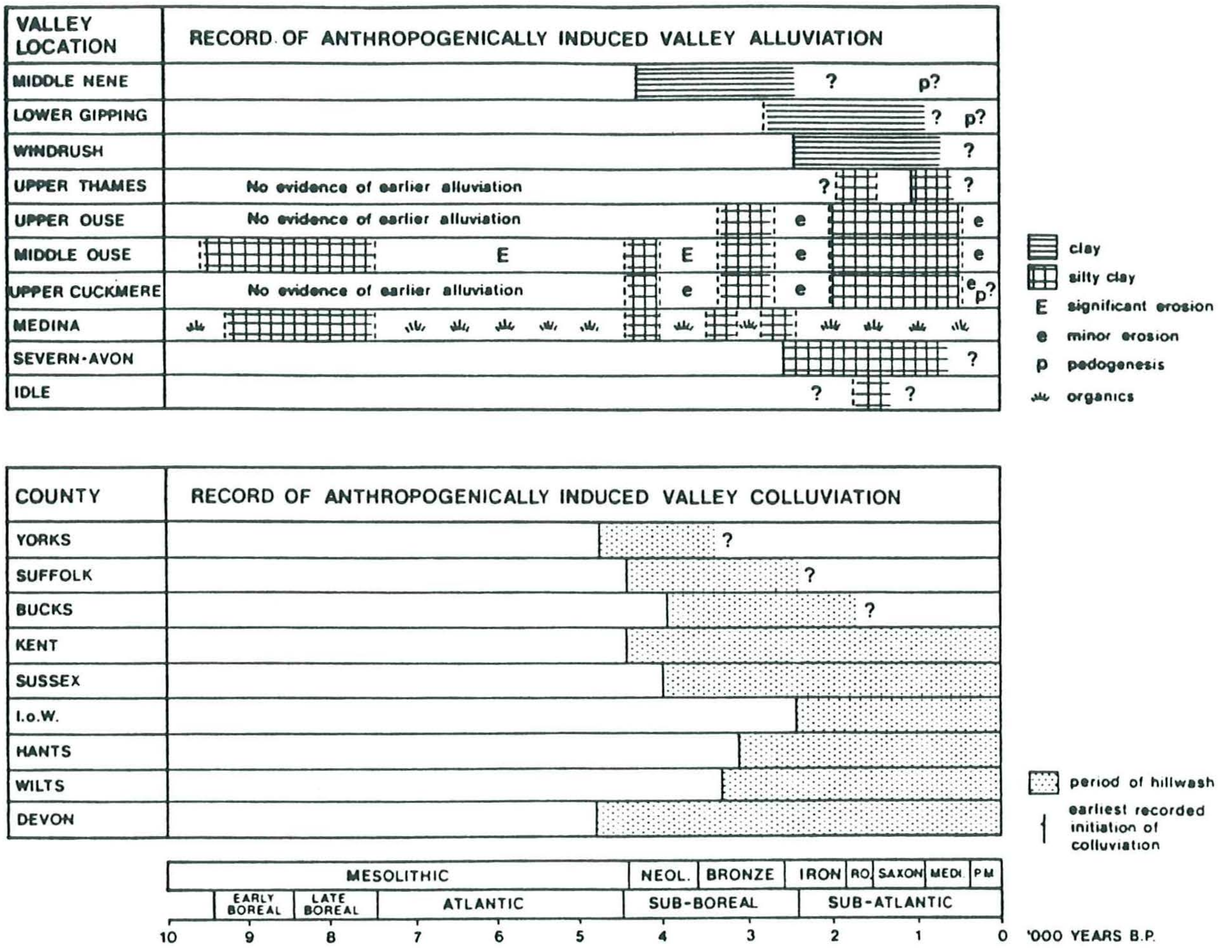

Figure 2 (From Burrin and Scaife 1988)

A good example of this sequence was reported by Shotton (1978) in the lower Severn and Avon valleys. Here, an upper layer of Keuper-derived reddish silty clay occurs in all sections regardless of the underlying sediment types. Various radiocarbon dates suggested that the onset of the upper alluviation occurred in the late Bronze Age and he concluded that it was due to human clearance activities, leading to accelerated soil erosion. Values for the effect of clearance on erosion parameters are quoted by Limbrey (1978). They include a 22 - 60% increase in rainwater reaching the ground, assuming a closed canopy is removed; a 5-30% increase in water yield after 30-50% clearance of the catchment; and a sediment yield from tilled soil up to 2000 times greater than that from undisturbed forest. Although large variations are recorded amongst these types of parameters, there can be little doubt of the strength of the erosion/sedimentation effect. Whether the situation is as simple as Bell's (1982) summarisation suggested is less clear. Burrin and Scaife (1988) challenged it on the grounds that their valley fills were far more complex, containing a variable sequence of interbedded sands, silts, clays, marls, tufas and peats often exhibiting different stratigraphic characteristics at different sites within one valley. They also found a greater width of dates, with some sites accumulating anthropogenically induced material as far back as the Mesolithic (see Fig 2). Dates for more recent alluviation are also available. For example Macklin et al. (1991) reported both a Bronze Age phase associated with clearance and a post-medieval phase arising from the disturbance caused by coal-mining on moorland in Northumberland. Similar phases are described by Evans (1991) from the upper Kennet in Wiltshire.

Conclusion

A common thread runs through most of the processes discussed here and is linked to the manner in which they have been interpreted. Many of the processes can be considered Catastrophic (in the mathematical sense) since they are characterised by gradual change towards a threshold at which the system shifts to a new semi-stable state. Catastrophe Theory has been mooted as an approach to the sedimentation of valley fills (Burrin and Scaife 1988); it also seems to apply both to podzolisation and peat accumulation. Barber (1982) pointed out that some North European bogs are on a climatic hinge-line where surface wetness is only just within (or outside) the limits required for peat growth. In his example, the argument was that these areas would be highly sensitive to climatic change, but the same approach can be used for anthropogenic effects. Human impact on such areas would clearly be out of proportion to the extent of the activities.

In many cases it seems that the mid-Holocene was a period of forest-maintained stability very gradually approaching thresholds beyond which the old system could not be maintained. The advent of forest clearance gave the "final push" to those systems whose stability was tenuous (or nearing the threshold) while leaving non-sensitive areas almost unaffected. In this scenario, the apparent degree of the human effect on soil between the Neolithic and Iron-Age is not only skewed by the ubiquity of earthwork-based data (as discussed under Podzolisation), but also by the greater availability of suitable systems, sensitive enough to undergo catastrophic change. Later clearances of more robust systems, for example on clay soils, would show significantly less apparent change in preserved profiles.

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