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Northern Regional Review of Environmental Archaeology: Geoarchaeology in Northern England II: Site Review, Discussion, and Research Priorities

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Summary

The content of many of the eighty or so site-based geoarchaeological studies in, or relevant to, Northern England has been examined, summarized and clustered into themes. All geoarchaeological studies have been subdivided into sections on the basis of the main theme or method of work. The study demonstrated the strong potential of geoarchaeology to aid archaeological interpretations, highlighted a selection of research priorities, and showed the need for a production of more widely accessible publications in refereed journals. Only in this way will geoarchaeology be able to improve the state of the art and influence of the scientific, archaeological and 'layman' communities.

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Contents

Tables

Chapter 1. Geoarchaeological studies in Northern England

1.1 Introduction

The content of many of the eighty or so site-based geoarchaeological studies in, or relevant to, Northern England has been thoroughly examined, summarized and clustered into eleven main themes. A discussion of each theme is given in Chapter 2, where all statements and recommendations concerning present and future geoarchaeological studies are strictly based on the evidence obtained from the descriptive site review. A simplified list of all the geoarchaeological work reviewed for Northern England is given in Table A.1 a, b and c in the Appendix.

In this chapter, the geoarchaeological studies are subdivided into sections on the basis of the main theme or method of work. Thus, since some site-based studies relate to more than one theme or method, different observations concerning a site may be found in two or more relevant sections. In such cases, a given thematic/methodological section will describe the main site/study features relevant to that section, with cross reference to the other sections where the same site is described. Although this results in a few repetitions, it allows the reader interested in only one theme to gain a general picture of a site or study.

Table A.1 describes most geoarchaeological work carried out in Northern England since 1974. In the period 1974-1984, geoarchaeological studies were mainly undertaken by the Ancient Monuments Laboratory; these were generally short, site-based and descriptive (Table A.1a). In the next decade (Table A.1b), geoarchaeological studies were more numerous, although the number carried out by the Ancient Monument Laboratory remained approximately the same. In this second period, the volume of work for each study was larger and reports became more detailed, following more closely international terminology and methods.

Before 1982, many studies were simply descriptive, and often their results consisted of archive reports and data information sheets. Though it is useful to have such information, such reports rarely describe the investigative methods employed, thus allowing little comparability of these sites with later ones. From the late 70s - early 80s work became more inquiring and, though almost always site-based, it also became more research oriented. Thus, from 1982, citations of method sources become more frequent, though they are not always present.

1.2 Mainly descriptive works

The first geoarchaeological studies carried out by the AM Laboratory between 1974 and 1977 (Table A.1a) included basic descriptions of one or more variables such as sample depth, pH, colour, organic matter content, presence/absence of countable pollen, texture, stoniness, mottles, horizon definition, and the presence of charcoal, earthworms or roots, with no interpretation. The approach probably resulted from the nature of the archaeological interventions at that time and, particularly, to a lack of field information, often resulting from the fact that traditionally there was not yet much space for geoarchaeological specifications and planning before excavations (see Section 2.3). Only in the late 70s did geoarchaeological data begin to be accompanied by the related interpretations, the first example being a study on Seamer Carr which, besides giving a descriptive account of colour, structure, texture, stoniness and some nodules, also includes interpretations of burning features and indications of lack of evidence for human activity in the site area (Abrahams, 1977a).

A study on Kirkhead Cavern, Cumbria (Abrahams, 1977b) also follows field descriptive criteria but, for the first time, employs drawings and maps to describe the distribution of the features and variables analysed. Again, however, no specifically geoarchaeological or archaeological interpretations are given.

Water content and loss-on-ignition of 603 sub-samples of archaeological deposits from the General Accident site at York were investigated by Jones (1987). The work was carried out in order to interpret the concentration of animal and plant remains and includes descriptions of sample variability. There was high variability between sub-samples, so the results were reduced into three main groups. The large variation in water content and loss-on-ignition of the sub-samples was thought very significant with regard to the interpretation of the concentration of plant and animal remains recovered during other analyses. Data were stored for later comparison with biological information such as the concentrations of insects, plant remains and parasite ova.

The importance of accompanying soil analysis with field work is highlighted by the scarcity of significant sediment/soil evidence in several investigations where no field information was available. An example of this is the evaluation of sediments from excavations at St Mary's Abbey precinct Wall in York (Jaques *et al.*, 1996). Although macromorphological description of some sediments was carried out, lack of any information on sampling, field relationships and site history reduced the possibility of significant interpretations to the minimum. In this case, the geoarchaeological scientist (the present writer) had been provided soil and sediment samples with no other site information.

1.3 Field work, sample descriptions and the multidisciplinary approach: the first steps and later developments

The importance of field work in geoarchaeology is described in Chapter 7. A brief discussion and research suggestions outlined on the basis of the site studies mentioned in this section is given in Sections 2.2 and 2.3.

The first geoarchaeological reports in Northern England did not include illustrations. From the late 70s onwards, the use of maps and drawings became more and more frequent - though still often insufficient. The first studies to make the change utilised simple hand-drawn maps and profile sketches to describe texture, structure, pH, and PO_4 distribution (Abrahams, 1977b and c).

Analytical work integrated a geological and pedological account at Wharram Percy, North Yorkshire, where soil series names were given to the various units on the basis of the available soil survey records (Abrahams, 1977c). Soils were grouped into three major types, and drawings of soil catenas were also provided. Seven archaeological sites were located in areas with different soil types. Some of the organic materials containing pottery were interpreted as having been used as fertilizers and it was suggested that some gleyed calcareous soils could represent organic topsoils, and charcoal fragments could have originated in burning of trees during deforestation. However, the author stated that these were only hypotheses, and suggested that supporting evidence could be obtained by carbon-dating, mollusc analysis and "detailed discussions with archaeologists and possibly other fieldwork". Though this work is simple and of limited extent, it includes the important elements of field and soil description and mapping, in conjunction with other soil/sediment analysis, their interpretation and/or some hypotheses with recommendations for their testing.

A multidisciplinary approach was also employed by Keeley (1977c) to describe soils from Manham Hill and Hopper Hill (Seamer Carr), and to compare data from these sites with the surrounding natural soils. This approach allowed the interpretation of some deposits as wind-blown materials accumulating during the Mesolithic. Furthermore, at Hopper Hill, there was no evidence of human occupation from the ditch filling materials. They were highly similar to the present top soil.

Deposits beneath a medieval context at Monkgate, in Kingston-upon-Hull, were sampled in a vertical sequence (Taylor, 1977). Features such as presence of charcoal, soil structure, lamination, colour and consistency are reported without field or site description, and interpretations are based on information other than that presented in the report, including: identification of occupation and non-occupation layers, identification of palaeo-groundsurfaces, identification of periods of landscape stability/instability, waterlogging and flooding.

It was not until 1970 that geoarchaeological sampling was carried out using monolith tins or other boxes suitable for obtaining and storing undisturbed soils columns. Keeley (1979) was one of the first geoarchaeologists who tackled the problem of sampling for geoarchaeological investigations by laboratory description of undisturbed samples collected in soil columns. The method had been previously in use by pedologists for many years, but only rarely for archaeological investigations. Analysing soil columns in the laboratory offered the possibility of spending more time examining undisturbed soils after the excavation was concluded, therefore by-passing some of the problems of carrying out soil descriptions in very short times, as is often required in rescue archaeology (see Usai, forthcoming). The approach, if used alone, has the limitation of not providing the whole field evidence together with spatial field variations. In fact, Keeley (1979) also found that, though she could describe soil columns and analyse many features in them, she could not give sufficient interpretation of disturbance/plough marks, and that it was "rather difficult to resolve this problem without having examined the material *in situ*". The problem is still the same today. However, due to its many advantages, the collection of undisturbed samples has now become a common procedure in geoarchaeological studies.

Macroscopic observations of soil columns in and about a section through Hadrian's Wall at Lannerton Farm, Appletree (Cumbria) were more effective in suggesting considerable human activity prior to building of a bank and a possible soil truncation before the Wall's construction (see Section 1.11). Four similar soil columns from Turret 10A, the wall and vallum of Hadrian's Wall at Throckley (Tyne and Wear) were described on the basis of colour, texture, presence of earthworms, charcoal, coal, brick and macromorphological features such as structure, roots, mottles, stones and gravels and nodules (Keeley, 1981). Disturbance of the buried soils was confirmed by plough marks, and post-burial precipitation of oxides (see also Section 1.11).

A study of soils from West Heslerton was the first geoarchaeological work in Northern England known to the author where methodological sources are quoted (Macphail, 1982). Other studies on the same site were carried out with a multidisciplinary approach (Macphail, 1991; see Section 1.6).

Investigations of soils from Winterton Roman Villa (South Humberside) included descriptions of texture, inclusions, stones, mottles and colour, and analysis of pH, loss-on-ignition and particle size (Keeley, 1988). The results showed high variability in the local soils, and that the villa had been sited so as to avoid droughty or wet soils while exploiting local loams. Variations between samples were attributed to various factors, including differences in soil parent material, other natural processes, and anthropogenic factors such as dumping or cultivation. Again, more definite conclusions about the source of materials and their variations were not possible because samples were not collected by the author who, therefore, was not able to observe them *in situ*.

A similar set of techniques was applied to a number of soil monoliths and samples collected by the Carlisle Archaeological Unit during excavations at Castle Street, Annetwell Street, and The Lanes in Carlisle. Results were correlated with geological and pedological descriptions of the area, and to the definition of major soil associations (Keeley, 1989). The combination of all these techniques suggested that the area was subjected to waterlogging before occupation. Marshy conditions were suggested in places where topsoils were rich in humus. This evidence, and comparison with other buried soils from Annetwell Street and Fisher Street, suggested that, prior to the Roman period, the area where Carlisle is now was waterlogged for much of the year. The area was probably used for pasture, though a few better-drained parts might have been cultivated. Samples showed evidence for human occupation, and it was suggested that the nature of soils would have made them unattractive for agriculture.

Macro-morphological soil descriptions, classification into associations, and measurements of pH, particle size and organic carbon allowed the identification of truncation of a buried soil from excavations of a long barrow (2900 - 3000 BC) at Ling Howe, North Humberside (Keeley, 1989).

A sequence of two buried soils overlying the rampart of a 2nd century Roman fort and subsequently sealed by medieval structures in Tullie House, Carlisle were identified by McHugh (1989b). Methods used included multivariate macro-morphological soil description . The high degree of soil development in the upper soil profile was interpreted as representative of a period of stability when plant growth and soil-forming processes were active. However, the truncation of the lower soil profile, together with the sharpness of the A/B horizon boundary, suggested only a short time had elapsed during which there was development of soil properties. Textural discontinuities in the rampart and the upper and lower soil profiles suggested that the topsoil of the truncated profile overlying the rampart was probably not *in situ.*

Material associated with an early Iron Age square ditch barrow complex at Seamer (North Yorkshire) was investigated by McHugh (1989c) through field investigations and their correlation with existing soil survey reports. Buried soils were identified and it was recognized that in the past they had been subject to higher water content than present, though probably were not permanently waterlogged. Two phases, one of deposition and one of stability, were identified for materials filling a ditch.

Mineral material filling voids and replacing wood tissues from a buried cart wheel rim and spokes, and their surrounding fill of chalk gravel, from excavations of Iron Age deposits at Garton Station (Humberside) were also investigated with a multidisciplinary approach (Limbrey, 1991; see Section 1.6*)*.

Another example of a thoroughly multidisciplinary approach is a study of soils, peat enclosing "sand cones" with Romano-British greyware, and till deposits with timbers dated to 5840 BP from an archaeological excavation at Grange Park Farm, near Beverley, N. Humberside (McHugh, 1993a; Young and McHugh, 1995). The site was in a very shallow peat-filled river valley joining the River Hull. Stratigraphic units included sand cones within sequences of pebbly sands followed by clay (buried subsoils), in turn followed by lower, middle and upper peats dated by ^{14}C to 2090, 1310 and 1170 years BP, respectively. Methods included heavy mineral, particle size, micromorphological, pH, peat humification, nitrogen, carbon, and hydraulic conductivity analyses. The grain morphologies in the sand cones were all similar and a lower bed of massive sandy silt loam, in lateral continuity with pebbly sandy horizons beneath the sand cones, displayed features (such as preferred orientation of particles, laminated coarse matrix, organic pans and oriented woody tissues) suggesting disruption and redeposition by water. The upper peat included humified fragments of alder, birch and willow wood, as well as intact leaves. At the westernmost edge of one the numerous ponds located around Grange Park Farm, two oak timbers dated to 5840 BP were found in till material underlying the peat, and the similarity between their ring sequences suggested that they were part of the same tree.

Interpretation of the data from Grange Park Farm led to suggestions that the sand cones were remnants of former spring orifices. The till where the timbers were found was interpreted as the Skipsea Till (see Usai (forthcoming) Chapter 5). It was suggested that peat accumulation had been influenced by spring activity. The similar heavy mineral assemblages in the sand cones, upper and middle peats, and in the upper parts of the till below the peat, as well as sand-grain morphology and particle size distribution, showed a progressive sorting in favour of lighter constituents as the sediment was transported by discharging groundwater through the springs to the peat mires (McHugh, 1993).

Correlations between hydraulic conductivity analysis, stratigraphy and analytical evidence, including radiocarbon dating indicated that the peat started accumulating about 2090 BP, after the drier period of the mid-Sub-Boreal and that spring discharges associated with the growing peat (represented by the sand cones) decreased later as the climate improved. However, a rise in the base level due to a rise in sea level (the 'Romano-British transgression') allowed continued accumulation of humified peat.

Correlations with analytical groundwater data and models applied throughout the region led the authors to establish that the dry valley system of the East Yorkshire Wolds remained above the regional water table throughout timber emplacement, early peat accumulation and cessation of spring activity during the periods around 5800 BP, 2000 BP and 1300 BP respectively at Park Grange Farm (Youngers and McHugh, 1995).

Field studies, macro- and micromorphology, analyses of wood and plant remains, phosphorus analysis and pH measurements were all employed for the investigation of soils and sediments from excavations at St Giles Hospital, Brough St. Giles, North Yorkshire (McHugh, 1993). Micromorphology and phosphorus levels suggested a gradual accumulation of occupation wastes and that the soil had supported plant growth at some time. The results of phosphorus analysis are summarized in Section 1.7.

An example of combination of geoarchaeological methods with archaeobotany and invertebrate analysis is given by the study of sediments, soils and biological remains from Roman deposits buried beneath a feature interpreted as a parade ground for the Roman fort at Stanwix, Carlisle (Hall *et al.,* 1994). Soil field observations were complemented by macro-morphological sample description, and organic sediments were processed using the techniques of Kenward *et al.* (1980; 1986). Pollen and other microfossils were examined superficially, using the method of Dainton (1992). Paleosol layers were identified beneath the Roman parade ground, whose textural and physical characteristics were such that water could flow down through this layer to the buried soils below. The horizon sequence included a buried light brown sandy clay subsoil horizon. Dense infillings of apparently organic material often occupied the thin root channels of this horizon and showed a morphology suggesting downward movement of fine particles in the profile. These layers overlay another buried subsoil (bBg) horizon, a grey-brown sandy clay with rare roots and very frequent mottles more abundant towards the lower part of the profile - consistent with intense and prolonged waterlogging. Locally, between the mineral soils and the parade ground, was a black, highly humified, organic stratum with a sandy component and a clear, distinct lower boundary, described in the field as an 'old ground surface'. In places, this layer appeared to fill narrow linear grooves in the underlying bBg horizon, interpreted by the excavators as the result of ploughing.

Biological observations of this dark layer suggested that, at the time it was developing, the area was, at least initially, a rather damp grazing land, perhaps with areas of scrub nearby. The large and unevenly distributed quantities of organic matter in this layer indicated a long period of stability in which decay could take place steadily. It was tentatively suggested that the grazing land soil had developed over an irregular surface left by the last episode of ploughing, the organic material filling the plough grooves as it formed (rather than organic matter having been introduced into these grooves by 'ploughing through', which seemed improbable in view of the nature of the organic layer). A second stage of organic deposition was represented by patches of plant material including brushwood and hay with some cereal grains and an insect fauna probably representing stable manure, from horses which could have been working at the site during the construction of the parade ground (although other interpretations were possible). It was also suggested, in agreement with the excavator's interpretation, that the brushwood component could have been used to consolidate wet ground (though it could also have arrived with dumped stable manure), and that disturbance by human activity was likely to have occurred, possible processes being stripping of turf, trampling, and mixing of the original topsoil into the parade ground.

This work showed that the combination of pedological and biological techniques was very successful for a preliminary interpretation of the site. The study was also useful for the investigation of past cultivation (Section 1.5).

Evidence of textile processing was sought in excavations at Beverley Eastgate, Humberside (Evans, 1987), through sample analysis with various solvents. Solutions of the complexing agent EDTA were able to isolate traces of madder from one sample. Soils were defined as 'clay systems with inclusions of small amounts of calcium carbonate'. A positive result from a uric acid test was accepted as indication of cess deposits with urine in another sample, and the presence of urine was considered to agree with an hypothesis of textile processing, as it was suggested that urine could have been used as a detergent or to dissolve dyes. Thus, it was concluded that textile processing, certainly fulling, and probably also dyeing, had taken place on the site.

Intensive studies based on a multidisciplinary approach, including field work and macromorphological sample description, were carried out in multiple stages at Beeston Castle, in the Stainmore area, and at Low Hauxley. These are considered in the following sections.

Studies at Beeston Castle

The first of the five AML reports on Beeston Castle describes investigations of soils from the areas that had been exposed within the Outer Ward and at the main gatehouse ('Square Tower') to investigate pre-medieval soils and prehistoric surfaces (Macphail, 1980c). Successive reports on the same site describe soil investigations from an extension of the previous excavations to further prehistoric surfaces where numerous bronze artefacts, including axe heads, a spear-head (in the Outer Ward) and prehistoric ditches and defences (at the Gateway) had been found (Macphail, 1981d). Soil profile descriptions and pH measurements showed that the bronze axe head was contained in an incompletely bleached Ea horizon of humo-ferric podzols. The axe seemed to have remained in a soil environment where eluviation was only partial and organic matter and sesquioxides had accumulated. High soil pH was attributed to excess of calcium ions caused by the construction of medieval masonry fortification with the use of mortar. Interpretations of the darker soil layers included those of a possible organic rich soil bed or a mixture of cultural material including charcoal, which penetrated into the soils as a result of trampling of people and stock in an entrance area (Macphail, 1981d). Other analysis on the organic status of the soils was carried out later, and all pre-1984 soil studies on Beeston Castle were summarized by Macphail (1984). Later, these studies were complemented by Macphail (1988) with micromorphological analysis (Section 1.6), discussions on pollen analysis (Section 1.4) and ^{14}C datings of samples from a prehistoric ditch fill.

Stainmore sites

Soil from five sites located along a East-West altitudinal sequence from 300 m. OD (Vale House Farm) to the Stainmore summit, including the Red Cross Marching Camp, the Bowes Moor field system, a 340-370 AD signal station, Coach and Horses earthworks, and a site named Vale House Farm, were investigated by McHugh (1992a). Later, McHugh (1992b) investigated soils from the Ravock Moor field system (NY 960145) in the same area. The studies employed a multidisciplinary approach, including soil survey, mapping and description, micromorphological analysis, identification of organic remains, correlations with existing pollen data, radiocarbon dating of humin, measurements of clay content, pH, carbon and nitrogen content and, for some of the soils, particle size distribution and heavy mineral analysis. An attempt was also made to establish the extent of soil degradation and gleying processes by assessing different forms of iron and aluminium extractable in solutions of sodium pyrophosphate (approximating to organically associated forms of iron and aluminium), acid ammonium oxalate (for inorganic and organic amorphous forms of iron and aluminium) and sodium dithionite (most forms of iron).

The results showed that the cool humid uplands soils evolved towards "nutrient depletion, acidification, physical decline and increased surface wetness, gleying, podzolisation and the accumulation of organic matter", as a consequence of the post-glacial woodland decline and subsequent vegetation successions in the uplands. On the basis of radiocarbon dates and other evidence, it was suggested that the soils observed at Red Cross started to develop during the mid to late Bronze Age (when settlements already existed further downslope). It was suggested that removal of trees would have enhanced soil wetness, leaching and soil decline; overgrazing would have favoured the less palatable species of plants such as bracken and led subsequently to reduced grazing rates and the invasion of heath type vegetation.

Observations of the soils buried under the field systems suggested a complex land-use system which began during prehistoric times, with peat starting to accumulate on flatter plateau areas to the north during Neolithic times (approximately 5340 BP). On the margins of the plateau, peat started to accumulate during the Bronze Age, *c.* 3620 BP, but open woodland was still a major landscape component, and evidence of arable cultivation was found in adjacent areas (McHugh, 1992a).

A thin organic horizon which had accumulated throughout the area of the field system, and which indicated vegetational change and increasing soil wetness, was dated to 1876 BP and the environmental change therefore placed in the Iron Age/Romano British period. The fact that 100m to the east of the field system peat had developed 1744 years earlier (3620 BP) suggested that the field system was in use for a considerable time after 3620 BP, although cultivation ceased well before about 1876 BP. The development of stagnopodzols was interpreted as the result of abandonment possibly during medieval times, as a result perhaps of peat encroachment from the North. The other sites studied in this area gave a more fragmentary information on land-use history. The buried soils at the signal station indicated that the processes of soil degradation (such as active podzolisation, surface wetness and organic matter mobility) were well advanced before burial, and the presence of mor humus type indicated minimal disturbance and limited utilization.

Micromorphological evidence of contexts from the signal station (which was constructed circa AD 340-370) showed that, before organic matter accumulation, intense disturbance had occurred within buried subsoils, perhaps during the Bronze Age/early Iron Age, possibly as a result of local woodland clearance. Organic soils within a rampart indicated that peat was developing locally by the 4th century AD. The morphology and chemistry of the signal station ditch fill suggested a prolonged period of local land surface stability following the construction of the signal station. Evidence was found for renewed activities, perhaps cultivation, and it was suggested that by circa 1055 BP peat was beginning to develop on the sloping plateau margins around the signal station in a possibly abandoned or scarcely grazed landscape dominated by *Calluna.*

The buried soils of the Coach and Horses earthwork contained evidence for prehistoric disturbance and early cultivation. Erosion and wind disturbance occurred during the second half of the 1st century AD, as shown by wind-sorted soils deposited over an *in situ* profile, and ceased during the first half of the 2nd century AD, as indicated by the radiocarbon date of overlying peat, possibly during the advent of the Romans.

Radiocarbon dates for buried turf lines at the Vale House Farm earthwork suggested renewed agricultural activity in the area between the mid 7th-10th century AD. Pollen evidence and the morphological and chemical characteristics of the buried profiles suggested that soil conditions and vegetation varied locally prior to enclosure, with grasses predominant in slightly drier areas, and Ericaceae, rushes and bracken over wetter ground to the North. The less degraded nature of the enclosure profile suggested a possible improvement in drainage, surface runoff and organic matter accumulation on the steep slopes, or limitations imposed on the accumulation of the organic matter through prolonged usage for grazing, harvesting or hay-making.

On the Northern margin of the Ravock field system there was evidence for a complex history of soil formation and erosion, which probably started during prehistoric times (McHugh, 1992b). Later, subsoil removal was attributed to agricultural activity, followed by a period of stability and the deposition of new colluvially-derived soil. The evidence for limited development of the soils during this stage was attributed either to a reduced time interval or to continuous (grazing) management limiting soil-forming processes. More recent soils at the same site were buried by the upcast of a Roman aqueduct, and were characterized by a more intense development, leaching and acidification prior to burial, culminating in the development of a humose topsoil.

To summarize the soil evidence from all the sites investigated: intermittent human activity occurred on the margins of the Pennine plateau (McHugh, 1992a). A phase of exploitation occurred during the middle to late Bronze Age times, "ranging from pastoralism in the more exposed areas above 440 m OD to arable agriculture in slightly more sheltered upland areas from 426 to 385 m OD". Scattered woodland possibly persisted on the plateau margins, where there was some intermittent clearance and woodland regeneration, whilst woodland persisted for much longer at lower altitudes. During the Iron Age the area become less heavily used for agriculture, as a result of deterioration of soil conditions and climate. However, in areas such as the Bowes Moor field system, pastoralism continued till the late Iron Age. By the late Iron-Age/Roman transition, land-use was probably restricted to pasture. Roman agricultural activity was very limited, though advent of the Romans led to erosion features which could be related to road building, construction, or increase in grazing. Evidence was found of later renewal of agriculture possibly during the second half of the 7th century AD at lower altitudes, and during the last quarter of the 10th century AD at the Bowes Moor field system, which has been in constant use since reclamation during the 10th to 13th centuries. Though evidence showed that the land was mainly used for pasture, it was also shown that the enclosures had been periodically cultivated.

Low Hauxley

An example of the usefulness of the combination of pedological field work, micromorphology and catenary interpretations of buried paleosols for archaeological interpretations is represented by investigations of paleosols and sediments from excavations near Low Hauxley, Northumberland (Payton and Usai, 1995a). Soil survey and analysis were carried out on materials from a trench excavated during an archaeological investigation in a sand dune belt approximately 1 km south of Low Hauxley, behind a small headland at the north end of Druridge Bay, Northumberland. The trench had been excavated following the discovery of two Bronze Age cairns, cists, cremations, inhumations and much earlier midden deposits containing shells of about 7000 BP, together with typical late Mesolithic flint artifacts, and mammalian remains during an excavation in 1983 (Bonsall, 1984). Paleoenvironmental work on deposits from this excavation suggested stratigraphic correlations between the cairn sites and a sequence of paleosols and peats buried under sand dunes, and exposed for more than 800 m along the coastline to the north of the cairn site. A new, 50 m NE-SW trench (DI) sub-parallel to the coast line was excavated and a geoarchaeological investigation was carried out with the aim of understanding palaeoenvironmental conditions and providing information that could be correlated with the archaeological evidence (Payton and Usai, 1995a).

Macro- and micro-morphological observations of five soil profile pits (D1A, D1B, D1C, D1D and D1E, from South to North) showed that the succession of the five profiles was a palaeocatenary sequence on glacigenic deposits. The catena was characterized by an approximately S-N sequence starting from (Profile D1A) a buried stagnogleyic argillic brown earth[1] with some admixture of blown sand in the buried top (A) horizon, frequent coatings made of clay, silt or opaque oxides lining grains and voids a lower [argillic (Bt)] horizon, and decayed tree roots, rare clay coatings and sand- and grit-sized flint[2] fragments in the sub-soil (Bw horizon). Since flints are not present in the soil parent material (the till deposits of the Northumberland coastal plain) their presence here suggested that they could be fragments of Mesolithic and Neolithic artifacts found elsewhere on the site.

Northwards in the catenary sequence, this profile was followed by a buried typical stagnogley soil[3] (Profile D1B), defined as a surface water gley soil affected by prolonged seasonal waterlogging. Further north in the sequence was a buried humic gley soil (Profiles D1C and D1D) with an eluvial (2Eg) horizon developed in a thin stoneless silty clay deposited in standing water prior to peaty topsoil formation. Finally, the last profile (D1E) towards the north was a peaty groundwater gley soil with 28cm of humified, eutrophic amorphous peat at its surface overlying a grey, eluvial (Eg) horizon with iron precipitation (gley) developed in stoneless silty clay. Thus, the degree of soil waterlogging increased downslope and soils changed first into seasonally waterlogged cambic stagnogley soils and then into more permanently waterlogged groundwater gley soils (humic gley soils). The last initially possessed a humose Ah horizon passing downslope into well developed humic gley soils with a progressively thickening peaty topsoils (Oh horizon) once the main former wetland depression was reached.

Since the nature of the buried topsoil horizon changed substantially with position on the slope, mainly in response to changing soil hydrological conditions, the palaeo-groundsurface at the time of the construction of Cairn No. 1 (as referred to by Bonsall, 1984) was within the peaty topsoil (Oh horizons) of Profile D1E. This meant that peat had started to accumulate in the depression before cairn construction.

Evidence for additions of wind-blown sand to different parts of the soil catena during the time interval between the construction of Cairn No.1 and Cairn No.2, suggested that the palaeo-landsurface at the time of the construction of Cairn No.2 was then at the surface of the bAh

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1 Characterized by an horizon sequence: bAh - Bw(g)- Btg. Argillic = rich in clay coatings.

2 Fragments of silica in the form if microcrystalline chalcedony with a mosaic 'salt-pepper' morphology

3 Horizon sequence: bAh - Eg - Btg - BCtg

horizon in Profile D1C, at the surface of the Oh1 horizon in D1D, and near the surface of the Oh2 horizon in Profile D1E. Also, evidence of a gradually increasing input of wind-blown sand during the later stage of profile formation suggested that the buried land surface was affected by dune encroachment about the time that Cairn No. 2 was constructed. It was also suggested that the supposed Bronze Age cairns were constructed on leached brown earths occupying a well-drained hillock to the south of a peat-filled wetland depression. Micromorphological evidence from the closest profile to the cairn site suggested that clay coatings had formed during profile development before burial and that this phase of soil formation had lasted at least 3000-5000 years, the time generally required in lowland Britain to build up a significantly developed argillic horizon.

Pre-burial soil-forming processes interpreted from soil thin section evidence included wetting and drying, biological processes (including vegetation development) and former soil structure development. The presence of biotic aggregates in the bAh horizon, and lines of structural weakness arranged in a pattern similar to that of a weak subangular blocky structure in the buried subsoil, suggested that either the old soil micro-structure had been partly obliterated by post-burial compaction or, alternatively, soil structure was limited or weak even during the time of profile differentiation. Thin section analysis also demonstrated a well-developed root channel network in the 2bAhg. The network disappeared completely in the overlying Eg horizon and was therefore pre-burial. Both pre- and post-burial iron mobilization and mottling were shown in the field by the spatial catenary relationships of mottle distribution. The thin stoneless silty clay found in one of the central profiles thickened towards the middle of the peaty depression. Field and micromorphological evidence (laminar banding of the fabric of the groundmass into clay-rich and silt-fine sand-rich layers) suggested that it probably represented ponding of water in this low-lying area prior to peat formation.

The soil investigations thus provided evidence for the character of the wetland environment immediately prior to peat formation and the palaeocatena of soils provided a critical link through the palaeo-groundsurface between the site of the cairns on the hillock and the surface layers of the buried peat in the adjacent former wetland depression.

1.4 The combination of geoarchaeological and pollen evidence

Despite the effectiveness of the combination of geoarchaeological and pollen evidence (see Chapter 7), the two techniques were associated only in a small number of studies in Northern England.

Soil pH and pollen from Norton Priory, Runcorn, Cheshire were investigated by Macphail and Keeley (1978). The work first gives a historical perspective and background to the site and then describes pollen analysis with identification of species and consequent site interpretation.

The potential for pollen analysis of soils from Beeston Castle (Cheshire) was investigated with pH, loss-on-ignition and organic carbon analysis (Macphail, 1983). Results showed that, in contrast to other soils at Beeston Castle, the soils under investigation were acid and consisted of two well-sealed organic-rich horizons suitable for pollen analysis.

Soil and pollen evidence from Beeston Castle was also combined with micromorphological analysis of a ditch fill (Macphail, 1988). Data suggested that "a Late Bronze Age ditch was cut in a wooded environment although open areas for agriculture were probably contemporary with the occupation of the site". Pollen from the top of the ditch fill indicated that the area had became re-wooded by birch and oak first, and then by alder and hazel.

Cores from a moat in the grounds of Belmont Hall, Great Budworth, Cheshire, were analysed by description and parallel pollen analysis (Canti and Weir, 1995). Combination of the two methods led to understanding that the lower 15 cm layers of organic sediments could be contemporary with the original site occupation, whilst some upper sediments appeared to be probably less than 200 years old. This seemed to suggest some dredging but not a full clean out of the moat.

Pollen evidence was also employed to enhance soil analysis in the Stainmore area of the Northern Pennines (McHugh, 1992; see Section 1.3).

Recommendations for further research with a combination of geoarchaeological and pollen evidence are summarized in Section 2.3.

1.5 Past cultivation

Some of the issues related to the general problems concerning investigation or recognition of past agricultural practices are summarized in Usai (forthcoming, Chapter 7), whilst this section is only concerned with studies in Northern England. Here, investigations on past cultivation have either been carried out on the basis of the recognition of past agriculture through archaeological evidence or, conversely, with interpretations or reconstruction of past landuse, specifically agriculture, being based on soil, stratigraphic and field evidence.

The presence of ancient plough marks, particularly when buried by more recent deposits, provides archaeological evidence for past agriculture. The existence of plough marks and turf-line formations was identified in soil columns of materials buried below occupation layers of AD 80-120 in Carlisle, Cumbria (Keeley, 1979a). Here, soil profiles consisted of very gravelly layers overlain by humic horizons which in turn were below the Roman/pre-Roman boundary. Field evidence revealed during the excavation was defined by the author as insufficient for profile interpretation. The hypothesis was suggested, however, that abundant silts could have been incorporated into the pre-AD 60/120 topsoil during ploughing and before turf formation. The area could have been flooded and there could have been two periods of ploughing before the earliest Roman occupation - this possibly indicating a standstill phase between the ploughing and Roman activity, during which the turf developed. It was also suggested that a pH just above neutral (probably caused by the presence of down-washed calcareous material) did not allow pollen survival and thus there was no evidence for local vegetation.

Ard marks were also found in buried soils from excavations of Turret 10 of Hadrian's Wall at Throckley, Tyne and Wear (Keeley, 1981). Ploughed soils found under construction levels associated with the turret (see also Section 1.11) were described (Bennet *et al.*, 1983). Here, clear evidence for cultivation was given by the presence of a series of 9 cm to 4 m long cross linear plough marks, each filled with material identical to the overlying soil, and mainly following a ENE-WSW or NNW-SSE direction. Description of colour, texture, mottles, structure, stones and roots was carried out, and the poorly drained soil was tentatively classified as a cambia stagnogley. Observing the distances between 120 consecutive marks, it was suggested that there had been a minimum of six ploughing operations and that the topsoil layer had been removed before construction begun. It was also suggested that the clear evidence of successive ploughing operations indicated "the possibility that the field was allowed to remain fallow between periods of cultivation or that there was only occasional ploughing followed by cultivation with lighter implements". The authors suggested a likely "cultural and chronological context of Late Neolithic-Bronze Age, 2500-2000 BC, when so much of the British landscape was first enclosed and marginal soils fully exploited".

Paleosols and other deposits containing narrow grooves interpreted as plough marks, buried beneath a feature interpreted as a parade ground for the Roman fort at Stanwix, Carlisle, were investigated by Hall *et al.* (1994). The study, (see Section 1.3), showed the high potential of the combination of biological and geoarchaeological methods and confirmed the primary importance of archaeological features such as plough marks for the diagnosis of past cultivation. In the same area, plough marks were also identified in other pre-Roman soils at sites at Tarraby, Stanwix and Knowfield (all near Hadrian's Wall), and their significance and the possible influence of ploughing on contemporary and/or underlying soil horizons is currently being investigated by the present writer. Micromorphological evidence from the same sites (Tarraby, Stanwix and Knowfield) has also been employed to test the validity of dusty/sandy/silty coatings for the identification of past agricultural practices (Usai, 2000).

Dusty coatings in materials from ditch fills and Iron Age surfaces at West Heslerton (see Section 1.6) were interpreted as an indication of possible past agricultural practices (Macphail, 1981). As a reference for this interpretation, the author quotes Kwaad and Mucher (1977; 1979). Likewise, cultivation has been suggested as the explanation for observations made on deposits at the Readfearns Glasswork (York) site, where some soils were rich in similar pedofeatures, charcoal and organic matter (Macphail, 1987; see Section 1.6).

In order to construct hypotheses on the interpretation of calcitic, clay, silt and fine sand void coatings often associated with silt-sized organic and fine opaque debris from excavations at Ferrybridge Henge, in West Yorkshire, it was accepted that, on the basis of work by Jongerius (1983), "concentration features comprising primarily silt, fine sand, fine organic and charcoal debris can result from long continued tillage and arable practices", but it was also emphasized that "any disturbance leading to the exposure of a soil surface or continued deposition of soil debris over a vegetated profile with continuous voids, could lead to their development" (McHugh, 1993).

Pedological features of soil monoliths and samples from Castle Street, Annetwell Street and The Lanes in Carlisle were investigated by Keeley (1989) (see Section 1.3). Some of the materials showed signs of anthropogenic disturbance but not of cultivation. Evidence for gleying and comparison with other studies previously carried out in the area suggested that it was not particularly suitable for agriculture - being waterlogged and probably marshy during most of the year - before Roman occupation, and was therefore mainly employed for pasture. The author suggested that only patches of better drained soils could have been used for arable agriculture (evidence of agriculture was found in the occasional ard marks in buried groundwater gley soil with deep humose topsoil).

The approach employed for investigating past agriculture has been different and has changed with time, as discussed in the next chapter (Section 2.8). For example, the combination of soil survey and description, soil macro- and micromorphology, soil chemistry, pollen evidence, heavy mineral and particle size analysis, and radiocarbon dating were useful in understanding various phases of agriculture within predominantly pastoral land in the Stainmore area in the Northern Pennines, (McHugh, 1992). In two enclosures pastoral usage was interrupted by cultivation in the 18th century. Evidence for addition of lime, coal, charcoal and slag, was interpreted as an indication of gardens. Buried soils at the "Coach and Horses earthwork" (see Section 1.3) gave evidence of prehistoric disturbance and early cultivation associated with cord rig. It was suggested that the termination of agricultural activity was marked by the presence of an overlying organic soil dated 2216 BP. Agricultural activity at the "Vale House Farm earthwork" (see Section 1.3) between 1300 and 1000 BP was deduced from radiocarbon dates of buried turf lines combined with pedological and mineralogical evidence. Different phases of land-use were suggested, including a phase of exploitation during the middle to late Bronze Age times, with pastoralism being practised in the more exposed areas above about 400 m OD, and arable agriculture in more sheltered upland areas from about 400 to 800 m OD. It was also suggested that agricultural activity of the Romans was very limited, but that there was evidence for a later renewal of agriculture possibly around AD 676 at lower altitudes and AD 979 at the Bowes Moor field system. In conclusion, though analytical results seemed to show that the land was mainly used for pasture, it was also suggested that the enclosures had been periodically cultivated (Section 1.3).

A discussion of the significance and possible tools for investigations on past agriculture and suggestions for research priorities are given in Section 2.8.

1.6 Applications of soil micromorphology and microscopy

Most micromorphological work in Northern England has been one-off studies on different sites; these are summarized in this section. However, repeated micromorphological studies at the same site were also carried out at different times during a period of several years for materials at Beeston Castle (already described in Sections 1.3 and 1.4) and West Heslerton, described in the next sub-section. A general discussion on soil micromorphology in geoarchaeology is given in the next chapter (Section 2.6).

In addition to 'classical' applications of micromorphology to soil or sediment materials, some micromorphological studies in Northern England concerned a wider range of archaeological deposits, such as blocks of ramparts, samples of materials replacing wood in parts of a cart, calcium carbonate concretions and ditch fills.

Micromorphological investigation of blocks constituting a rampart of an early 2nd century Roman North Wall at Watertower Street, Chester led to hypotheses concerning the procedure for the rampart construction (Canti, 1990; see also Section 1.9). Micromorphological analysis showed that the basal block of the rampart contained dark matter discretely mixed with paler fabric more typical of the rest of the rampart, and that sharp boundaries between pale and dark matter could not result from pedological processes but probably come from mixing or trampling. Micro- and macro-morphological evidence, as well as mineralogical observations and particle size analysis, suggested that rampart blocks were initially cut from topsoils and then laid down in reverse so that, progressively, more of the lower part of the soil profile was laid down toward the upper part of the rampart, and fine dark organic lines were deliberately laid between the blocks.

Stereo-microscope examination combined with micromorphological and particle size analysis of material replacing the wood of a buried cart-wheel rim and spokes, together with the surrounding fill of chalk gravel, from excavations at Garton Station (Humberside) were carried out by Limbrey (1991). The non-calcareous nature of the clay fraction suggested that it was derived from decalcified, probably argillic soils of the Wolds, eroded during a period of arable farming. Micromorphological methods showed that clay and silt had been carried into the grave pit as a result of stream flow in the valley floor, and had coated the spaces left by decay of the wooden wheel as well as spaces between the chalk pebbles packed around it. Micromorphology also showed that silt and clay did not infiltrate in such a way as to infill or replace the wood as it decayed, but were, rather, deposited as laminae which initially followed the contours of the chalk fragments which had pressed against the wheel. Later, deposition became more lenticular possibly as a result of water dripping rather than flowing into the vacant space. Meanwhile, the quantity of silt progressively decreased, until the centre of the space was eventually filled by clay with very little silt. The lenticular structure was also visible under the stereo microscope, in a form thought to be characteristic of clays when wetted. The effects of bioturbation in thin section appeared to be mainly in the clayey areas, and were shown by the by disruption of the laminar structure, mixing of material, burrow formation and infill (Limbrey, 1981).

Calcium carbonate concentrations diffused into the matrix of soils from pit alignments and ditches of late Neolithic to early Iron Age at Ferrybridge Henge, in West Yorkshire, were investigated using micromorphological analysis (McHugh, 1993). The features were interpreted as the result of *in situ* solution of carbonates adjacent to biotically active voids, with local translocation and re-precipitation leading to a relative enrichment in clay minerals within the adjacent soil, and were attributed to local CO_2 production and, by implication, a biotically active soil environment. Agricultural practices or other factors causing soil disturbance were interpreted as possible causes of the formation of calcitic clay, silt and fine sand coatings often associated with organic matter and fine opaque debris (see Section 1.5). Calcified plant root remains and well developed crystalline calcite features within a soil underlying pit fills were interpreted as possible results of de-carbonation within upper infill layers.

Different aspects of calcium carbonate deposits in archaeological contexts were highlighted with the micromorphological analysis of anthropogenic deposits from excavations at Flixborough, Humberside, where exceptionally well preserved bones were found in unconsolidated blown sands (Canti, 1992c). The deposits included extensive dumps of ash and Middle-Saxon burials, occupation ditches and surfaces, with evidence for timber walls, various iron, bronze and lead objects, and evidence for iron working. Deposits interpreted as having formed through human activity, including soils, a range of man-made to semi-natural ditch fills, ash and other dumps, were analysed with micromorphology. The analysis suggested that wood ash and other calcareous materials had contributed to maintaining a high pH and thus to the preservation of bones. Thin sections showed no evidence for lengthy exposure of the ash layers, nor of micro-sedimentation structures in the ash layers resulting from rainfall or wind. This was interpreted as a possible indication that the ash layers had been dumped rather than deposited slowly. Orange clay-sized material lined the majority of the surfaces of weathered bones, including internal pores. No such coatings, however, were found on the better preserved bones. In fact, almost wholly unweathered bone fragments were seen in a highly calcareous matrix including ash, limestone, shell and also charcoal, shell-tempered pottery and sandstone. This, again confirmed the possibility that the presence of abundant ash and calcareous material could have prevented bone weathering. Some slides showed a high concentration of fragments of ceramic and charcoal. Observing that, if orange coatings lining weathered bones were the result of bone decay, then similar material present in the soil fabric could represent the products of large amounts of bone now vanished, Canti suggested that such coatings could constitute an important object of further research. Other non-micromorphological investigations of material from the same site are summarized in Section 1.9. All other micromorphological studies carried out in Northern England have concerned more conventional materials from soil profiles, peat or other sediments.

Two soil profiles under peat from Tintwistle Moor were investigated with both soil micromorphology and particle size analysis (Canti, 1993). Evidence was found for erosion, sorting, podzolisation and peat development occurring at various scales in time and space.

Micromorphological analysis was employed in order to integrate a suite of other methods for the investigation of soils, till, and a sequence of peat beds enclosing "sand cones" with Romano-British greyware, and timbers dated to the 6th millennium BC from an archaeological excavation at park Grange Farm, near Beverley, East Yorkshire (McHugh, 1993a and Younger and McHugh, 1995). Micromorphology supported the analytical evidence and helped to elucidate the stratigraphic and climatic sequences and to establish that the sand cones were remnants of former spring orifices (see Section 1.3).

Micromorphology and field study were combined with phosphorus analysis for soils from excavations at St Giles Hospital, at Brough St Giles, North Yorkshire (McHugh, 1993; 1997). Micromorphological analysis helped the identification of a Neolithic/early Bronze Age paleosol and of an anthropogenic soil sealed by charcoal-rich sediments, dated 310 BP. Micromorphology, together with field evidence, plant and phosphorus analysis, suggested that the soil had supported plant growth and that household, fire and garden waste deposits had accumulated gradually, whilst evidence for rapid dumping of biologically active soil over a primary ditch fill suggested a radical disturbance, possibly resulting from agricultural practices.

Micromorphological assessment of thin sections from excavations at Withow Gap, Skipsea, N. Humberside, was employed to complement other large scale soil/sediment descriptions from the same site (Usai, 1994). Samples at the field scale had been analysed by McHugh (1993, unpublished) and the micromorphological assessment was aimed at establishing the potential of thin sections for archaeological interpretation. The evidence showed a sequence of basal silty humus forms (*gyttja*) overlain by a peaty sequence, in turn overlain by well-developed soil mineral (B) horizons. Evidence for periodical waterlogging in the upper layers and more prolonged waterlogging in the lower layers was observed. Thin sections also showed an input of sand during the deposition of the peat and during soil formation. In this case, micromorphological analysis highlighted the absence of any significant evidence for human activity, but confirmed the potential of the investigations for paleosol and palaeoecological studies.

A micromorphological assessment of soils and sediments from excavations of trenches across the Antonine fort, rampart and ditch at Thornbrough Farm, Catterick, N. Yorkshire, was also carried out (Usai, 1995) in order to complement a soil/sediment assessment by McHugh

(1993, unpublished). In this case, too, micromorphological observations did not add much information to that obtained from the field work, although it was useful for a confirmation of the latter.

An example of the importance of combining micromorphology with pedological field work for archaeological interpretations is given by studies on paleosols and sediments from excavations near Low Hauxley, Northumberland (Payton and Usai, 1995). The investigation was carried out on materials from archaeological excavations in a sand dune belt approximately 1 km south of Low Hauxley, at the north end of Druridge Bay, Northumberland, where coastal erosion had exposed Mesolithic and Bronze Age archaeological remains, including burial cairns, cists, mammalian remains, midden deposits and artifacts, as well as layers of buried soils and sediments below more recent sand dunes. The work is summarized in Section 1.3.

West Heslerton - repeated micromorphology at different times on the same site

Macphail (1982) investigated soils and sediments from excavations at West Heslerton, near Malton (North Yorkshire), where Neolithic urn cremations and ditches, Bronze Age barrows and ditches, Iron Age huts, hearths, pits, ard marks, and Anglian burials were all discovered. Soil work included auger survey, site and profile description (see Section 1.3), and measurements of pH, loss on ignition, alkali soluble humus, organic carbon, and particle size distribution; micromorphological interpretations and investigations were carried out by both describing and counting different features. Blown sand, up to 50-60 cm depth, and generally alkaline, in places containing Neolithic urns, was found in much of the area. Soils with Iron Age ard marks and occupation areas were described as podzols buried by neutral to alkaline brown sand.

Two areas (L and M) contained materials described as deep blown sand plough soils and Early Bronze Age barrows pre-dated by Neolithic ditches. Complicated micromorphological evidence and lack of pollen or snail evidence only allowed the suggestion of the following sequence of provisional hypotheses: agricultural practices had been carried out during the Neolithic and local soils, perhaps still rich in bases, were weathered and transported because of sand blow; during the Early Bronze Age barrows were constructed, probably of turf-like material, and later blown sand buried them; conditions stabilized with woodland cover causing acidification and formation of brown earth soils, probably followed by clearance and agricultural disturbance; heathland invaded and remained until the Iron Age, by which time humus-rich podzols had developed and turf mounds had been altered to organic-mineral horizons typical of podzols (Bh horizons). Further agriculture caused soil erosion and ard marks which were buried by blown sands in which new podzols developed. Erosion and deposition sequences continued and in Anglian times base-rich blown sands caused a higher pH on the site; in post-Anglian times, the soils acted as brown earths, with an active earthworm population, and have been used for agriculture. For another area (E), the author suggested that Iron Age agriculture stripped the soil to the underlying mineral podzol horizons produced by post Early Bronze Age agriculture. The material, which contained ard marks, was eroded and mixed with the blown sand.

Some pre-barrow and post-barrow ditch fills contained dusty coatings interpreted as a possible indication of past agricultural practices, and many stone and bone fragments whose pores were filled by clay coatings. Some Iron Age surfaces were interpreted as podzol horizons of pre-Iron Age, and also contained dusty coatings. Pre-barrow ditches cut into brown earth were also interpreted as an indication of agricultural practices (probably Neolithic). A period of stabilization and woodland development after the late Bronze Age was suggested on the basis of the micromorphological evidence for clay translocation in an acid environment. The presence of charcoal in such coatings suggested that secondary woodland clearance, burning and possibly agriculture had all occurred in later Bronze Age times. This would have favoured heathland formation and the onset of podzolisation during which periodic burning was again practised. Podzolisation would have lasted until the Iron Age, when the author suggested the occurrence of a new phase of disturbance with stripping off of the eluvial and B horizons typical of podzols. Iron Age surfaces were later buried and podzolisation continued until Anglian times.

Later, more geoarchaeological work was carried out at the same site and included investigations of Neolithic pre-barrow ditch fills, Early Bronze Age pre-barrow ditch fills, a pre-barrow surface, barrow mound material, a Late Bronze Age/Early Iron age surface and plough soils and hollow-way ditches (Macphail, 1983). Micromorphology showed the presence of typical podzol horizons (*spodic* horizons) with fine charcoal distributed in the Bronze Age barrows, the post-barrow ditch fills, and the Iron Age surface, the last two also exhibiting dusty coatings. Features in the Iron Age surface were described as low-porosity 'plough pans' and possible ardmarks. Macphail explained that micromorphological evidence was complicated and interpretations were limited by the presence of sesquioxides and amorphous organic coatings, but a pedological reconstruction could be given as follows:

Pre-barrow ditches were probably cut into base-rich brown earths, and the lower ditch fills derived from moderately unweathered local soils. Lack of charcoal in some primary ditch fills suggested that filling occurred when activities such as clearance and cultivation had temporarily ceased. Upper ditch fills derived from more mature soils were probably transported by wind. Where podzolisation was not represented in the soil fabric, it was suggested that a base-rich soil, where earthworm activity had obliterated the original characters of mound materials and any evidence of an old ground surface, might have developed. Both pre- and post-barrow ditch fills gave evidence for initial translocated material and a succeeding phase with dusty coatings and infillings containing charcoal, all suggested woodland clearance, burning and possibly agriculture. Late Bronze Age heathland development would have caused podzolisation and the vegetation could have been regularly burned, as suggested by the presence of charcoal in sesquioxidic and organic coatings. Podzolisation could have lasted until the late Bronze Age/Early Iron Age, as already described by Macphail (1981).

Later soil studies at West Heslerton were summarized by Macphail (1986). Further soil investigations, including field and laboratory soil descriptions, were carried out in 1991 on one area (2BB) of the site (Macphail, 1991). It was suggested that a sand sequence in the area was an unpodzolised pre-Late Bronze Age hillwash soil (over natural lacustrine sands) which pre-dated darker brown blown sands of late Bronze Age to Anglian date, when podzolisation was affecting the area. Weak podzolisation could probably have affected stabilized Anglian soils. Particle size distribution, pH, $CaCO_3$ percentage, loss-on-ignition and magnetic susceptibility analyses showed that the upper sands were more cemented and acid, contained more organic matter, and had a higher magnetic susceptibility than the lower layers, interpreted as a possible indication of higher iron content and human impact (burning).

1.7 Studies including phosphorus analysis

Although soil phosphorus is highly significant to geoarchaeology (Usai, forthcoming, Chapter 7), there have only been a few studies in Northern England where its analysis has been employed.

The first studies were carried out during the 1970s and made use of simple descriptive criteria to give accounts of phosphorus distribution in soils from excavations at Wilderspool, Warrington, Cheshire (Keeley, 1977a), Kirkhead Cavern, Cumbria (Abrahams, 1977b), and Manham Hill and Hopper Hill, North Yorkshire (Keeley, 1977c). Later, a number of postulated garden soils and landfill materials from Newcastle Quayside (Newcastle-upon-Tyne), were investigated with the aim of understanding their origin, use and relationship with the underlying materials (Sheil *et al.*, 1993). Methods included measurements of total and inorganic phosphorus, pH, particle size and micromorphological analysis (see Section 1.6). Some 14th century landfill deposits included minerogenic contexts and deposits composed of a mixture of loose soil, organic and animal residues, with carbon, bone fragments and shells, with a very high quantity of phosphorus, higher than that documented for most animal manures, though consistent with values reported elsewhere for carcass remains, chicken faeces and resistant bacterial residues associated with the guts of domestic animals.

Fourteenth century soil profiles occurred in midden/refuse type material, and included soil A horizons for which pH and phosphorus content were measured. Phosphorus levels were higher than documented values of total and organic values in topsoils (Wild, 1988), but were considered to lie within the range recorded for archaeological soils. Total and inorganic phosphorus values were 5 to 10 times higher than for deposits subject to intensive garden usage and anthropogenic soils from short-lived settlements, but were consistent with values recorded for deposits with prolonged settlement or intense occupation. Inorganic and organic phosphorus from mid 17th century soils was higher than the average for topsoils and higher than for anthropogenic or intensively used garden soils. Organic phosphorus levels were twice those expected in soils but consistent with some calcareous soils and manures. Thus, the study was able to establish that all the soil profiles were anthropogenic, to distinguish between short, long-term and intense occupation, to establish sources of phosphorus anomalies, and to verify that soil emplacement was followed by additions of loose sandy soils.

Phosphorus analysis was also employed to complement the studies of soils and sediments from excavations at St Giles Hospital, at Brough St.Giles in North Yorkshire (McHugh, 1993; 1997). Phosphorus levels of sediments/soils of Neolithic/early Bronze age at this site indicated that some human occupation and activity were short-lived or periodic, whilst phosphorus levels and micromorphology of the pre-medieval anthropogenic soil near the hospital (see Section 1.3) indicated gradual accumulation of sediments. Levels within the lower fill of a pit suggested the disposal of human wastes, and materials within a grave fill were successful in suggesting the presence of fine bone fragments.

Thus, though few in number, phosphorus studies have been valuable in achieving the objectives of providing information on the nature, origin and use of materials (see suggested research themes in the next chapter, Section 2.9).

1.8 The late Roman/early medieval urban *dark earth*

Within the North of England, Macphail (1980a) has described *dark earth* deposits from excavations of a Roman site at Keays Lane, Carlisle, which included a 2nd century AD wooden structure beneath a 3rd century stone building. Analyses included measurements of pH, soil colour, 'phosphate response', alkali soluble humus and loss on ignition on two samples. The author interpreted the results as indicating: a) the heterogenous nature of the *dark earth* (corresponding to similar results for sites near/in London), b) charcoal spread in the samples and c) the possibility that the phosphate and very abundant soluble organic matter derived from faecal material.

Similar analyses, plus studies of coarse inclusions, phytolith and pollen identification were carried out on two samples of *dark earth* from an excavation in the Bedern, York, by Macphail (1980b). The archaeological sequence site included Roman walls and presumed *dark earth* beneath medieval deposits. One of the aims of the analysis was to compare this *dark earth* with similar material in London. Pollen was present (but absent at the London sites). The similarity of this *dark earth* with that from London was deduced from the similarity of the coarse inclusions of stones, mortar, charcoal, bone, tile, pot and oyster shells. Evidence for an input of cereal pollen was interpreted as an indication that the site maintained a 'waste ground' flora (as present in sites in London) "which received additions of material with a probable high cess content including parasite eggs and likely secondary pollen grains of cereal and arable indicators", and that "grasses were possibly also collected elsewhere and utilised on the site". It was concluded that results from this and other sites showed that " the *dark earth* represents intensive use, rather than abandonment, and that although essentially an urban waste-ground deposit, as indicated by its physical structure and pollen content, it has accumulated through additions of material relating to perhaps domestic and stock usage. These include *Calluna* and grasses, which were perhaps utilised as floor covering, animal bedding, fodder or brushwood, and possibly improperly threshed cereal material either again as fodder or purely as domestic refuse. Lastly, inputs of obvious cess have been mixed with other general urban debris to produce a typical anthropogenic deposit" (Macphail, 1980b).

At a site in Chester, soils from a 2nd-3rd century road sealed by a 4th century wall were all buried under a *dark earth* deposit (Macphail, 1982). Methods to investigate the nature of a buried soil and of the *dark earth* included soil description, measurements of pH, loss on ignition, organic carbon and grain size analysis. The results showed that some of the soils were truncated, an organic soil was a road bed and the *dark earth*, different from the organic soil in its more abundant silt and stones, was of "dumped character", later used as garden soil possibly until the 13th century.

A discussion of some research themes related to the *dark earth* is given in Section 2.13.

1.9 Mineralogical work

A number of geoarchaeological studies in Northern England have been partly or entirely based on investigations of mineral species and assemblages. Techniques used have included optical microscopy, x-ray diffraction (XRD) or fluorescence (XRF) analysis and heavy mineral analysis - often in conjunction with particle size analysis and infrared spectroscopy.

Canti (1990) carried out geoarchaeological investigations on soils and sediments from excavations of part of the Roman North Wall at Watertower Street, Chester, where sections of the original turf rampart - constructed during 76-78 AD, prior to the stone wall of the early 2nd century - were exposed. Analyses for this site are described in Section 1.6. Investigations were aimed at understanding the nature and provenance of the blocks and inter-block materials/bands. The work was partly based on comparisons of the rampart materials with control samples of local soils. Results are described in Section 1.6. Particle size analysis showed that rampart samples were poorly sorted - this suggesting a mixed or chaotic depositional history perhaps involving more than one process - with highly variable fine fraction. Particle size diagrams for the control samples were different from those from the rampart, and only those made of local boulder clay showed curves similar to those for the sediments of the ramparts. Heavy mineral analysis indicated similarity in the mineralogies of the various rampart samples. Comparison with local soils showed that the mineralogies of boulder clay and local topsoils and subsoils were similar to those of the rampart except in the case of apatite, whilst the mineralogy of local pebble beds was quite different. An hypothesis was made that mineral suites were the product of three major sources: boulder clays (rich in clinopyroxenes), pebble beds (rich in apatite), and alluvium (rich in chlorite), with the mineralogies of most samples being similar to those of the boulder clay and, subordinately, to those of the local alluvium.

The particle size curves of local soils with mineralogies most similar to those of the rampart showed many similarities to the particle size curves for the rampart samples, though there were some differences between the particle size distributions of various other local boulder clay control samples and those of the rampart samples, explained as a possible result of sorting of the original source rock of the boulder clay. Though it was not possible to determine the exact location of the source material for the rampart blocks, the results showed clearly that the material originated from a boulder clay area with a well developed dark topsoil.

Ditch fill materials from Iron Age and Romano-British enclosure ditches found during excavations at the A1/A659 intersection near Collingham (West Yorkshire) were investigated by Canti (1991a). Other Iron Age features included a roundhouse, four-post structures, storage pits, and three inhumation burials. Particle size analysis showed a bimodal distribution of all samples from the different components of the ditch, and this was interpreted as possibly resulting from windblown material being added to a nearly unsorted deposit such as boulder clay or solifluction deposit. Comparison with samples of local soils showed that the ditch fills were no more than local soils dumped or fallen in the ditches. Heavy mineral analysis showed that the mineralogy of the ditch fill samples was broadly similar.

Particle size and heavy mineral analysis were also employed to investigate soil materials from the lawns of Brodsworth Hall, South Yorkshire (Canti, 1991b). Results from both analyses showed no significant variation between the lawn samples and samples from local fields, this suggesting that lawn and local field samples were formed from the same parent material.

Flixborough

Natural and anthropogenic deposits from excavations at Flixborough, Humberside were investigated by Canti (1992c). Micromorphological investigations at this site have already been described in Section 1.6. Middle-Saxon burials, occupation ditches and surfaces, evidence for iron working, various iron, bronze and lead objects, dumps of ash and exceptionally well preserved bones were found. A geological summary for the area of the site indicated that this was situated on sands covering a mudstone, ironstone and limestone scarp forming the eastern margin of the alluvial plain of the River Trent. Particle size analysis of five sand samples showed that these were almost identical despite the lateral and vertical variations of the sampling points. Results of particle counting and microscopic observations during reactions with hydrochloric acid showed that both samples collected at depth and samples closer to the surface had increasing percentages of calcite below ~150 μm, but only the deep samples showed the calcite increasing spread up to ~200 μm. The coarser, >400 μm fraction of the deeper samples was identified as a detrital assemblage of limestone, chalk, calcareous sandstone, tufa, shells and crinoid discs; the finer calcareous materials post-dated the coarser fraction in both shallow and deep sand, and consisted mainly of individual crystals of various shapes.

Various hypotheses were suggested to explain the distribution of the calcareous material. Two of these hypotheses were that the calcareous materials were either (I) part of an even distribution diluted by addition of quartz-dominated sand (in this case there would have been two sources for the aeolian sand, and fine calcite would not be authigenic[4], or (ii) they had undergone dissolution - but it was observed that this was at odds with the apparent growth of the fine calcite. The pH of the samples without coarser detrital grains (shallow samples) was around 6.6, whilst that of the samples with a coarse calcareous component (deeper samples) was more alkaline, around 7.6. This reflected the fact that the shallow samples were more leached than the deeper ones.

Particle size analysis showed a blown-sand content in all occupation deposits, including ash or other dumps, soils and ditch fills. Soils on an Anglo-Saxon ditch fill, as well as the uppermost buried soil layer on the site, however, had a particle size distribution more similar to that of the blown sand, this showing a lesser human influence than that for the other samples. Soil micromorphology showed that wood ash, too, contributed to maintaining a high pH and thus to the preservation of bones (see Section 1.6).

Interpretations of the taphonomy was that of a "weakly calcareous material, constantly undergoing leaching, but not yet having developed any significant acidity". The accretion of the sand since Saxon times was enhanced by a constant supply of calcium carbonate, in the form of limestone, tufa, chalk, shell and calcareous sandstone (detrital material) being added to the top of the profile. Such calcareous additions and the addition of wood ash prevented the acidification of the soils, which would have hastened bone weathering.

1.10 Preservation and decay of organic deposits

Sections 1.9 and 1.6 summarized site-based studies involved with problems and issues of preservation of *robust* (cf. Kenward and Hall, 2000) organic deposits in soils and sediments. Preservation and decay of *delicate* (*ibidem*) organic remains has been investigated in many site-based studies in Yorkshire carried out by the Environmental Archaeology Unit in York

[4] crystallized in sediments after their deposition

during the last 25 years. Recently, a critical summary of the most important findings of such studies pointed at the possible influence of soils and sediments on preservation and decay (Kenward and Hall, 2000).

The study describes how large amounts of remains of insects and plants deeply buried in anoxic conditions in soils and sediments were found very well preserved in many deposits in York and in rural sites in Yorkshire, whilst preservation was generally very poor in superficial deposits, where invertebrate remains were often reddened, yellow or pale, and plant remains were often represented by mineral-replaced or woody fossils. All materials appeared to have decayed rather evenly in post-medieval deposits, and unevenly in Anglo-Scandinavian or more recent deposits. Decay of organic materials in some deeply buried deposits, now in anoxic conditions, was attributed to pre- or immediately post-burial (rather than recent) degradation.

Research themes and hypotheses suggested by such findings are described in Section 2.5.

1.11 Hadrian's Wall sites

A number of different types of geoarchaeological investigation have been carried out in areas along Hadrian's Wall. Methodologies and approaches have been different or, in some cases, not comparable, but comparison of the available evidence can provide useful information and help the establishment of future research priorities.

Soil investigations in a section through Hadrian's Wall at Lannerton Farm, Appletree (Cumbria), described in Section 1.3, showed that buried soils pre-dating the Wall contained abundant charcoal, interpreted as an indication of intensive human activity prior to the building of a bank and that the buried soils could have been truncated before the Wall's construction (Keeley, 1980).

Geoarchaeological investigations of materials from Turret 10A, the Wall and Vallum at Throckley, Tyne and Wear, were carried out by Keeley (1982). Macro-morphological descriptions of soil columns from the excavations at this site showed that the columns were essentially similar to each other and suggested that buried soils had been disturbed, whilst the presence of ard marks confirmed that cultivation had taken place. Soils from excavations at the same site were also investigated by Bennet *et al.* (1983). Removal of the construction levels associated with the turret revealed a poorly drained soil up to 15 cm deep, tentatively classified as a cambic stagnogley, and containing charcoal. The presence of plough marks confirmed that cultivation had been carried out: 130 ard marks were identified in one area (area a), 49 of which lay outside the turret interior. Ard marks with a V- or U-shaped transverse section included a series of cross-linear grooves each filled with material identical to the overlying soil, and tending to follow a ENE-WSW or NNW-SSE direction, and being 9cm to 4m in length. Observing the distance between marks, the authors suggested that they indicated a minimum of six ploughing operations. Considering that the soil which remained was too shallow for a tilth, and that it is standard building practice even now to remove turf before cutting foundation trenches or building any permanent structures, it was suggested that the topsoil layer had been removed before construction began. The clear indication of successive ploughing operations indicated "the possibility that the field was allowed to remain fallow between periods of cultivation or that there was only occasional ploughing followed by cultivation with lighter implements" (Bennet *et al.*, 1983). Though the ard marks could not be dated, it was suggested that a cultural and chronological context of Late Neolithic-Bronze Age was likely.

Investigations of soils from excavations between Milecastles 61 and 62, at Crosby-on-Eden, in Cumbria, included particle size and loss on ignition analyses, descriptions of local climate, agriculture, geology and soils (Keeley, 1985). Buried soils from the excavated sections appeared to be podzolised, and were classified as stagnopodzols of the Dunsmore series. Characteristic podzol horizons (Bs and Bh horizons) were present, but evidence for wetness and the presence of a pale layer were interpreted as a possible indication that more than one process had acted on the soils. Absence of evidence for cultivation suggested that the soil supported a vegetation of acid grassland or moorland prior to the construction of the Wall. Buried soils here were similar to those seen at the nearby White Moss, underlying the Vallum bank.

Site and analytical work of soils from cultivated pre-Roman (*sensu lato*) deposits in Stanwix, Carlisle, have been described in Sections 1.3 and 1.5 (Hall *et al.*, 1994).

Preliminary pedological investigations of soils from the *Segedunum* Roman fort at Wallsend, North Tyneside, have been made with the aim of investigating and describing features pre-dating the fort (Usai, 1998). Field evidence showed buried topsoils and related Ap horizons arranged in ditches and burrows, which were interpreted as pre-Roman deposits.

The samples showed a full succession of soil profiles from A to mineral (B/BC and C) horizons, with charcoal and other burnt plant material dispersed through the whole of the profiles. In places burnt layers were present above the standard profiles. On the basis of field observations the hypothesis was suggested that the features interpreted by the excavator as ditches and banks were actually the result of pre-Roman ploughing activity. If further research provides sufficient information to confirm the interpretation, the site may assume regional significance for evidence of cultivation near Hadrian's Wall. This is particularly in view of the current work on sites at Knowfield, Stanwix and Tarraby, near Carlisle, also representing buried soil profiles with archaeological evidence for Iron Age or broadly pre-Roman agricultural practices along Hadrian's Wall (Usai, 2000 and in preparation).

Geoarchaeological work on a spur at the Birdoswald Roman fort (Cumbria) was carried out to investigate the causes of, and possible strategies to mitigate the erosion of the spur, which threatened the archaeology of the area and, locally, the Vallum ditch (Usai, 1998). The work, entirely based on pedological observations and field methods, showed that erosion was exacerbated by the fact that some soil types were characterized by a surface water table. This study confirmed, again, the importance of field and site investigation for geoarchaeological interpretations.

Some suggestions for further research are described in the next chapter (Section 2.15).

1.12 Geoarchaeological studies correlated with alluvial and colluvial sedimentation

Introduction and concepts

Human influence on valley sedimentation is a complex and multidisciplinary topic and not all of its aspects will be described here. For comprehensive accounts, works by Bell (1982), Bailiff (1992), Canti (1992a), Clark (1992a and b), Macklin and Needham (1992), Needham and Macklin (1992), Macklin (1993) can be consulted. Related concepts on the interplay between forests, soils, man and cultivation and their effects on valley sedimentation are also summarized in Chapter 7 of Usai (forthcoming).

In the British Isles, after the glacial periods, forests started to re-establish and stabilized the landscape until other factors, such as clearance, again reduced the woodland cover. Very little soil erosion occurred under forest and therefore very little sediment was loaded to streams (Limbrey, 1978).

In places, at different times, and to different extents, fires and large clearings followed, causing major changes in the water regimes, with large increment in superficial water run-off and stream flow, often with great seasonal differences. Thinning of forest affected water regimes less than reductions of trees in concentrated areas. Water run-off, by carrying soil, caused an increment in stream sediment load by a factor of more than 2000 in cultivated areas compared to undisturbed forest; erosion would also have been increased by strongly seasonal rainfall regimes (Limbrey, 1978).

Rises in groundwater levels resulting from forest clearance promoted the development of peaty lenses between accumulating alluvial deposits. Further, soils were moved by ploughing and animal feet at the edges of every stream, and increased the material transported by surface run-off, later to be redistributed by overloaded streams. Also, with increasing cultivation, massive amounts of colluvial soil were often accumulated in lower slopes, in dry valleys and against field boundaries, merging with finer flood deposits ('loams'), and resulting in relatively unsorted alluvium overlying better-sorted deposits. With increasing large-scale cultivation, channels became confined to meander belts and subject to regular overbank flooding until man intervened with canalization and drainage systems (Limbrey, 1978).

As Canti describes in his review (1992a), human influence on valley fills is the result of a "complex of anthropogenic and natural processes which are not easily disentangled". The author quotes the work of Bell (1982), who found that in many different valleys the British alluvial sequence includes fine-textured, highly organic and often reduced material in the lower parts of the fill, which resulted from slow, stable sedimentation of forested areas - though with occasional mineral bands resulting from episodes of increased erosion. At many sites in England, the overlying deposits are coarser, high mineral/low organic, oxidized sediments deposited as the result of accelerated erosion after forest clearance, which started between the Bronze Age and Romano-British times, with further thickening during the historical period as a result of large-scale forest destruction (Bell, 1982).

Canti (1992a) gives some examples confirming Bell's sequence description, but also quotes other studies describing different types of valley fillings, such as variable sequences with interbedded sands, silts, clays, marl and peat in successions often changing even within the same valley, characterized by a wide range of dates, and with anthropogenic material ranging from the Mesolithic to Bronze Age and much more recent dates (e.g. Burrin and Scaife, 1988). Canti also quotes other works describing valley sedimentation resulting from Bronze Age forest clearance and post-medieval sedimentation coinciding with mining on moorland in Northumberland (e.g. Macklin *et al.*, 1991).

It has been emphasized that river valleys have long provided a focus for human activity, exploiting an opportunity for settlement and utilisation of a wide range of resources, but archaeological investigations of such activity are faced with the problem of evaluating long-term geomorphological changes in river valleys which may have rendered the environmental context of former human activity very different from that of the present day (Passmore and Macklin, 1997). Also, the history of floodplains involves much local variation, for example in cases of encroachment of 'floodloam' over Roman sites. Limbrey (1978) describes the formation of lynchet fields, low terrace features resulting from the establishment of field boundaries along floodplain edges. In some cases a hedge remained in the position of the field boundary, but elsewhere the removal of the boundary gave cows access to the river when permanent pasture was created in former open fields, and as a result lynchets were left as terraces. Where field boundaries were present, they limited the redistribution of plough soil down the edge of the terrace and along valley sides. Build up of soil along the field boundary could create a larger area of land free from flooding and thus more suitable for cultivation.

Bedding caused by alluvial processes can be identified through study of the macro- and micromorphology of sediments but is not described in this review. A summary of some micromorphological studies of alluvial and colluvial sequences can be found in Courty *et al.* (1989). Though stratification and layering may be observed with the naked eye in samples and in the field, as well as in thin sections, it has been found that fine sands not showing any stratification or bedding in the field, may show fine bedding when the same layers were analysed using soil peels taken on the surface of soil monoliths (Valentine and Dalrymple, 1975).

Valley sedimentation: case studies in Northern England

Lynchet field types have been investigated in the Craven area (North Yorkshire), at Otterburn and Appletreewick (Tolan Smith, 1975). At Otterburn, intensive arable use since medieval times was established on the basis of field observations of slope gradient changes, and it was calculated that the amount of soil moved off the higher parts of the field as a consequence of man's disturbance was approximately 91 m^3, which corresponded to an average *c.* 10 cm thickness spread over the field.

Palaeoenvironmental investigations by Macklin *et al.* (1991) included a study of the chronology and nature of prehistoric and historic land use changes in a small river catchment in Coe Burn, Callaly Moor, Northumberland. This revealed two episodes of valley floor alluviation of middle to late Bronze Age and post-medieval date, and an intensively used landscape with evidence of late Neolithic to Bronze Age, medieval and post-medieval settlements. Magnetic mineral and geochemical analysis showed that sediments from the oldest alluvial till in the catchment contained soil-derived material, believed to have been produced by soil erosion resulting from Bronze Age tree clearance and cultivation, whilst deposition of younger alluvial deposits, less than 1500 years old, was associated with the inwash of bedrock generated by coal mining in the same catchment.

Geoarchaeological investigations on late Holocene alluvial fills and valley side sediments at *Habitancum* Roman fort, in the valley of River Rede, near West Woodburn, included morphological mapping, surveyed cross-sections of the Rede valley floor, sedimentological and pollen analysis, and radiocarbon datings (Passmore *et al.*, 1991). The study showed post-

Roman aggradation of Holocene terraces, and a Roman bridge abutment north-west of *Habitancum.* A feature thought to be a stone-built wharf was actually a natural product of post-Roman erosion. It was also suggested that the former watercourses adjacent to the fort and to a spur of land extending north from the fort were truncated palaeochannels of the Rede associated with three discrete alluvial terrace surfaces of different age (Passmore *et al.*, 1991 and Passmore and Macklin, 1997).

Investigations of fine-grained post-glacial alluvium in the middle Tyne valley showed significant contrasts in the chemical characteristics of late Holocene floodplain and channel sediments of the valley (Passmore and Macklin, 1994). It was suggested that statistical analysis and comparison of the characteristics of channel sediments, tills and alluvium from sites throughout the Tyne basin could show that geochemical variability was diagnostic of sediment provenance from geologically distinct sub-catchments. Heavy metal content could permit the identification of sediments derived from the South Tyne basin, particularly those arising from mining activity in the Northern Pennine orefield between the mid seventeenth and mid-twentieth centuries.

Post-glacial lateral channel migration and a net incision of valley floors in Northern Pennine river valleys resulted in widespread truncation and reworking of Holocene and earlier archaeological features associated with alluvial fills (Passmore and Macklin, 1997). Enhanced rates of lateral reworking during and after the late Roman period in the upper and middle reaches of the South Tyne suggested that preservation of *in situ* archaeological materials in many wide Northern Pennine valley floors is limited to the Roman and later periods. However, earlier Holocene and late Pleistocene terraces may have been the focus of long-term human activity and, in places (particularly in the middle reaches of the South Tyne), there is the potential for preservation of multi-period archaeological landscapes. It was also suggested that, although localized burial of former landsurfaces and associated archaeology could have occurred towards valley margins as a result of fan deposition, colluviation and, in upland tributary valleys, late Holocene peat development, it is unlikely that such burials extend over large areas, because of relatively limited rates of post-Roman overbank alluviation in the South Tyne valleys (Passmore and Macklin, 1997).

Pleistocene terraces along the middle reaches of the North Tyne seem to have great potential for preservation of multi-period archaeological landscapes as exemplified in the Gowandburn River Camp settlement of Iron Age, Romano-British and later date: "Widespread late Holocene alluviation of overbank sediment in the middle reaches of the North Tyne basin may...have concealed Iron Age and later archaeological landscapes and, allied to persistently high groundwater levels in these valleys (reflecting a net tendency towards alluviation during historic times), has ensured good preservation of organic-rich channel fills and possibly buried soils. The potential archaeological importance of these reaches has been demonstrated by the recovery of a large piece of a timber dated *c.*760-210 BC, clearly bearing tool marks and resembling a truncated plank from the base of a ... palaeochannel at Snabdaugh" (Passmore and Macklin, 1977).

Geoarchaeological investigations of the lower reaches of the River Tyne above the present tidal limits suggested that preservation of organic materials is rare in the freely drained terraces, dominant in the area.

To summarize, contrasts in relief, sub-catchment geology, land-use history and glacial influence across the River Tyne basin caused significant differences in past and present river environments and in the development of valley floors. Such differences are reflected in the archaeological potential: in most of the upper and middle reaches of the main tributaries, and particularly in the catchment of the South Tyne "the prospect of prehistoric archaeological material surviving in its primary context is limited to surfaces of Holocene and earlier terraces that have escaped later extensive channel reworking and incision during the historic period. Lower, and particularly tidal, reaches of the Tyne, by contrast, may have experienced widespread burial of multi-period archaeological landscapes beneath thick deposits of alluvium in waterlogged conditions that are favourable for preservation of organic materials. An important exception ....are the middle reaches of the North Tyne, where medieval and later alluviation buried floodplain surfaces and any associated cultural landscapes, including well preserved organic materials, dating between the mid first millennium BC and early medieval times" (Passmore and Macklin, 1977).

Chronology and patterns of development of past fluvial landforms of the valleys of the Hodder river system, in the Bowland Fells, where debris cones and alluvial fans pre-date the modern valley floor alluvial forms, were interpreted by Harvey and Renwick (1987). The study describes how the carbon dating of wood allowed two main phases of Holocene erosion to be identified with debris cone/fan deposition taking place between *c.* 5400 BP and *c.* 1900 BP and again at *c.* 900 BP.

2. Discussion, recommendations and research priorities

2.1 Introduction

The aim of this section is to establish research priorities and recommendations for geoarchaeological studies in Northern England. The review of site-based studies (Chapter 1) re-emphasised that both human occupation and the environment are strongly capable of leaving their impression on soils and sediments, and that geoarchaeological investigations are an important part of interpreting past human occupation and related issues. The following sections discuss a number of issues and questions, many still unresolved, which have emerged from the site review in Chapter 1.

2.2 Multidisciplinarity

Only some of the geoarchaeological studies carried out in Northern England, for example those by McHugh (1987; 1992a and b; 1993 a and b), Heyworth (1990), Canti (1990; 1991a and b; 1992c), the studies by Keeley on Hadrian's Wall, and Macphail at West Heslerton (Table A.1.), and those by Payton and Usai (1994), and Younger and McHugh (1995), were multidisciplinary and based on a suite of techniques. From this review, however, it is clear that pedological and sedimentological evidence is particularly useful when employed in parallel with other data, or as a test for other information or hypotheses. Often, geoarchaeological or pedological studies alone are not sufficient to contribute to an understanding of a site, nor to determine the absolute duration of certain processes occurring in the soil, such as clearance, cultivation, or soil development itself. Thus, it is suggested that, in order to attain more and better interpretation of soils- and sediment-related issues in archaeological contexts, greater emphasis should be given to interactions between geoarchaeological and other investigations at more stages of the work, including the planning stage.

Paleosols

The study of paleosols must be concentrated on those features that are the most persistent, rather than the more transitory ones which are likely to have formed or become modified in the more recent stages of soil profile development and are thus less diagnostic of past conditions.

The discussion in Usai (forthcoming, Chapter 7) and the site evidence of Chapter 1 has highlighted the fact that, in the case of paleosols, more important than the occurrence of individual features is their spatial distribution. Thus, even in the absence of extended outcrops of *in situ* paleosols showing variations resulting from soil/slope/water interactions, the properties of individual profiles and pedons should be considered with their spatial variation throughout the profile or pedon, rather than only as individual properties. Evidence from sites such as Low Hauxley, Beeston Castle, Flixborough and Stainmore (Chapter 1) showed that, though studies on paleosols involved different types of site investigation, different research procedures and sometimes contrasting approaches by different authors, soil and sediment information acquired a greater meaning when correlated and compared with other evidence (see Section 1.3). Individual features gained significance when considered in broader contexts and, in many cases, soil macro- and micromorphological properties, mineralogical features and physical features became important only when their variation with depth and with slope position or with the known archaeology and stratigraphy of the site was considered (Section 1.3).

Thus, for paleosols it is important to combine the interpretation of individual archaeological finds with the site three-dimensional distribution and arrangement of features.

Also, studies of archaeology-related paleosols (as, for example, at Low Hauxley - Section 1.3) have shown the usefulness of comparing features representing the known sequence of horizons of such paleosols to those of similar, present day, surface soils.

2.3 Quality of field work, sampling, mapping and drawing

Quality of geoarchaeological work

It has been discussed that in many cases the approach of pedological investigations during archaeological excavations has been different from or less accurate than the classical scientific approach. For example, geoarchaeological studies are often based on analyses including a number of replicate samples, but mapping is never carried out sufficiently accurately to be acceptable to soil surveyors or pedologists. This was partly because for many years numerous archaeological studies have been carried out as rapidly as possible in order to rescue finds/information, creating problems for the quality of archaeological soil investigations, particularly when these needed to be based on field work. For example this is probably why for three decades, during the 1960s, 70s and 80s, only rarely did geoarchaeological studies in Northern England include drawings or maps. Even recently the problem continues.

As already described by Keeley (1978), the geoarchaeologist in archaeological excavations has "no margin of error", in that the excavation must be visited exactly at the right moment before the features of interest have been destroyed - any further sampling at a later stage is generally impossible. Thus, "the fundamental research required to enable better interpretation of archaeological site investigations is, to a large extent, left undone" (Keeley, 1978).

Drawing and mapping

As shown in Chapter 1 and Table A.1, the first geoarchaeological studies in Northern England did not include drawings or maps. One of the first works making use of drawings is that of Abrahams (1977) and, during the 1980s, only a few works started to complement sampling with illustrations of some kind. Later, the use of maps and drawings become more frequent - though often they are still insufficiently employed.

Examples of cases where the qualities of geoarchaeological works would be greatly helped by some visual representation - such as drawing or map - are particularly those where soil/sediment samples are collected from a stratigraphical sequence (whether archaeological or not), when the sampling strategy is significant in itself, or when a restricted number of samples needs to be representative of many, or of an entire sequence. It is also important that soil/sediment stratigraphy is considered in the archaeological context, and that, if possible, soil/sediment site maps are correlatable to the available archaeological site drawings. Thus, in order to obtain better information, the geoarchaeologist should, from the planning stage, include maps and drawings as an important priority, and the archaeologist should provide the geoarchaeologist with the site plans and drawings.

Field work

The importance of field work in geoarchaeology has been described in Usai (forthcoming, Chapter 7) and is also highlighted by the scarcity of significant sediment/soil evidence in investigations where no field information was available. Absence or insufficient application of field work probably resulted from the nature of rescue archaeology and, only latterly, from inadequate specifications and subsequent planning. This is probably because specifications (and subsequent planning) in the field of environmental archaeology, have traditionally tended to focus on biological investigations, which were better established in the region (and, perhaps, in the whole country) than geoarchaeological studies. Thus, soil and sediment specifications have often tended to be incorporated into recommendations for bio-archaeological works, which in many cases can be carried out successfully without field work or mapping.

It is now evident, however, that the geoarchaeologist should be advised about an excavation at its planning stage, in order for him/her to plan and carry out sufficient site visits.

Sampling strategy

During the 1970s, no specific mention was made of the importance of the type of sampling strategy for geoarchaeological studies in Northern England. In many cases this probably resulted from the fact that the emphasis of the work seemed to be more on the descriptive record for archive purposes (see Section 1.2). The importance of a systematic sampling strategy was first highlighted by Canti (1990) who employed diagrams and photographs to illustrate micromorphological and pedological sampling, complementing each undisturbed sample with a bulk sample, and collecting samples from a number of representative local soils.

The sampling strategy is extremely important for the success and representativeness of samples for geoarchaeological investigations. This is particularly true because of the intrinsically variable nature of soils and sediments. In fact, by definition, soils change vertically and horizontally within profiles, horizons, and land units. Sediments also vary, though their variations display different patterns from those of soils. Variability of both is a characteristic which should always be taken into account. When samples are small, for example thin sections, many misunderstandings can be born of the assumption that one sample, or one thin section, is representative of a larger unit. Thus, it is important to define what the sample is assumed to represent.

Unfortunately, though it is well known that one thin section is not generally representative of a soil horizon, it is not always possible to carry out sufficiently representative sampling, particularly when the archaeological excavation is carried out rapidly. Though the harsh reality is that we have to overlook this in order to achieve some results without carrying out hundreds of analyses for each sampling unit or context, it is still important to take into account and define the limitation of the sampling strategy chosen, or at least to give the reader sufficient information (such as photographs/diagrams) on the exact location of samples and more general information on the soil/sediment of which they are taken as representative. Comparable materials from adjacent natural soils and sediments are invaluable for supporting the assumption of sample reliability.

Sampling and laboratory analysis to complement field work

Keeley (1979) was one of the first geoarchaeologists to tackle the problem of describing undisturbed soil columns in the laboratory. The method had been previously in use by pedologists for many years, but only rarely had it been employed for archaeological investigations. Analysing soil columns in the laboratory offered an opportunity to examine soils after the excavation was concluded, therefore solving some of the problems of having insufficient time to carry out sample descriptions on site, as is often the case in rescue archaeology (Section 2.4). The approach however, if used alone, has the limitation of not providing the whole range of field evidence and spatial variations. In fact, Keeley (1979) also found that, though she could describe soil columns and analyse many features in them, she could not give sufficient interpretation of disturbance/plough marks, and that it was "rather difficult to resolve this problem without having examined the material *in situ*". The problem is still the same today - see Usai (forthcoming, Chapter 7). Thus, it is important that the use of monoliths helps should always be accompanied by examination of the materials *in situ*.

Summary

To summarize the above observations in this paragraph: ideally geoarchaeological work in an excavation should be carried out in four stages: (1) communication between archaeologists and the geoarchaeologist from the planning stage; (2) planning geoarchaeological work at a sufficiently early stage to prepare a sampling strategy; (3) geoarchaeological field work; (4) post-excavation geoarchaeological work with adequate provision of archaeological information.

2.4 Ancient burning and resulting soil/sediment changes

Soils and sediments in archaeological sites may have undergone heating/burning for different purposes, and therefore at many different temperatures, for different time durations, and on different types of contexts and materials. Only a little evidence is available, however, on what the resulting soil/sediment changes are likely to have been.

It is generally assumed that burning results in reddening. However, a recent experimental study consisting of the reproduction of burning conditions similar to those of ancient hearths, demonstrated that, in fact, only rarely does burning and heating results in soil reddening (Canti and Linford, 2000). The work showed that some soils with coarse textures reddened when heated to temperatures below 450 °C, but other soils of finer texture and richer in organic matter did not redden even when heated to temperatures as high as 550 °C. The authors suggested that reddening can be influenced by other factors such as chemistry, quantity of ash and organic matter, and type of parent material, and strongly emphasized that more research is necessary on the factors affecting reddening, preferably through an interaction between both laboratory and site-based analysis.

No investigations on the significance of reddening have been carried out on sites in Northern England. In this review it has been emphasized that, since a red colour has been employed both to diagnose paleosols and to recognize burning on archaeological sites, it is clearly important to establish whether, and to what extent, the reddening is inherited from the source materials rather than being caused by recent oxidation or burning of iron compounds. Thus, more research is also needed in order to understand the criteria for distinguishing reddening and other soil/sediment changes resulting from burning/heating from those inherited or due to other causes, and to establish the reversibility of such changes.

Other important themes for research are establishing what mineralogical, morphological, magnetic, chemical or other changes occurred in soils and archaeological contexts when they were heated/burnt at different temperatures and for different durations and establishing the reversibility of such changes with time.

It is suggested that great value could be derived from experimental research, by simulating heating and burning of different materials, at various temperatures and for different times, and carrying out mineralogical, micromorphological, chemical and physical analysis of the affected soils, thus comparing the results to the features of archaeological contexts known to have been heated.

2.5 Preservation and decay

Chapters 7 and 1 have discussed the conditions of archaeological preservation, which depend greatly on soil water conditions. Examples of buried objects that were listed in Chapters 7 and 1 included pottery, flint, tools, coins, fabrics and leather; or organic remains of plants and animals such as wood, charcoal, pollen, seeds, snails, shells, bones and insects. As indicated in section 1.10, recent studies in Yorkshire highlighted that, whilst preservation of many insect and plant remains deeply buried in anoxic conditions was very good, fossils had strongly decayed and either become reddened, pale, yellow, or possibly even disappeared in many superficial deposits. Furthermore, although most fossils had decayed rather evenly in post-medieval deposits, decay was uneven both in spread and intensity in Anglo-Scandinavian and more recent deposits (Kenward and Hall, 2000).

In both soils and sediments, physical disturbance and disintegration may often be accompanied by chemical change. Soil pH also influences preservation and decay. For example, shells and bones tend to be easily altered and broken down in acid soils and better preserved in alkaline soils/sediments or when an alkaline input or any pH buffer is added to otherwise acid sediment/soil (as was found, for example, with sediments at Flixborough, N. Lincolnshire).

Preservation in soils and sediments has also been ascribed to redox potential affecting oxidation and reduction processes. Permanently waterlogged soils, where oxygen (indispensable to most organisms responsible for decay) is present in very limited quantities, are capable of preserving a variety of organic materials. In comparison, temporarily waterlogged soils preserve less effectively because of a periodical input of fresh and oxygenated soil water, or aeration as the water-table falls. Thus, interruptions to the waterlogging, whether seasonal, occasional or random, could favour decay. Though experience and observations on a number of archaeological sites seem to confirm this, further research is needed in a wide range of different situations.

Changes of preservational factors with time can greatly complicate interpretations, as shown by the following three hypotheses suggested by Kenward and Hall (2000) to explain the poor preservation of superficial deposits and the better preservation of deeper deposits in Yorkshire:-

1) Superficial layers recently suffered a reduction in water content.

2) There was a rapid decay around the time of deposition followed by stabilization.

3) There has been a gradual and more or less continuous decay since deposition.

Kenward and Hall also suggested important themes for long and short term research to achieve more understanding of the decay processes. Suggestions for long term research include "monitoring the condition of remains in relation to ground conditions over wide areas and for long periods", and "experiments with a long time span". Recommendations for short term research strongly focus on setting up laboratory experiments and carrying out field monitoring and observations, both aimed at understanding: a) the decay *rates* in relation to the initial conditions leading to burial, and b) the relationships between burial conditions and in-ground decay. The authors stress the urgency of systematic studies of this type, explaining that, as yet, there is insufficient knowledge even to classify the preservation state of delicate biological remains for the purposes of recording. Research approaches and ideas are also suggested. These are:-

1) examining the effect of recent deep cuts (such as cellars or sewer trenches) to explain whether an organic matter decay profile can be identified.

2) developing methods to separate decay which occurred around the time of burial from more recent effects by studying morphological/chemical changes.

3) establishing whether differential/preferential degradation of different types of more or less resistant biological remains "skews the evidence" we find today in the ground (Kenward and Hall, 2000).

It is clear that further research is urgently needed in a wide range of different situations, landscapes and soil types, to achieve a better understanding of how organic artifacts and biological remains are incorporated into deposits, the specific processes involved in decay, and the conditions favouring preservation of organic and inorganic materials. Soil micromorphology can be of great help for observing interactions and ordering different factors and events in the soils and sediments hosting fossils. If regional interpretations are attempted or general mechanisms for preservation/decay are to be established, it is important to make sure that the soils considered are representative of the landscape under examination.

Valuable information on the relationship between soils and preservation/decay in Northern England can be extrapolated from existing soil association maps (Soil Survey of England and Wales, 1983a and b). Thus, such maps, together with detailed on-site investigations, should be employed for future research aimed at establishing relationships between soils, settlements and preservation in Northern England (see Section 2.10)

2.6 Soil micromorphology in geoarchaeology

From the site review of Chapter 1, it appears that, in Northern England, soil micromorphology has been employed, for example, in site stratigraphy studies (Macphail, 1988); testing and complementing other analytical methods such as pollen analysis and ^{14}C dating (McHugh, 1993; Younger and McHugh, 1995); studies on provenance of materials and site sequences (Canti, 1990 and 1991a); investigation of soil forming processes (Canti, 1993); clay translocation (Limbrey, 1991; Macphail, 1982); studies on mechanisms involved in bone preservation (Canti, 1993); examination of infill processes, including ditch filling mechanisms, and studies on reconstructions of past environments (Macphail, 1982; McHugh, 1993); in combination with pedological field work (Payton and Usai, 1995a); studies on paleosols (Macphail, 1982; McHugh, 1993 and 1997; Payton and Usai, 1995a); and in testing the potential (of micromorphology) for palaeoecological studies (Payton and Usai, 1995a).

Many of these and other studies elsewhere have been aimed at using micromorphology to aid the recognition and geoarchaeological interpretation of soils and sediments. However, the basic concept of a need for interdisciplinarity and interdependence of micromorphology, pedology and archaeological evidence has often become diluted. Too frequently, micromorphology has become more of a self-reliant tool than an interdependent one, and thus lost much of its original meaning and validity. It is now important to re-emphasize a multidisciplinary approach to micromorphological interpretations, and to combine micromorphology with other types of evidence.

Though micromorphology has been applied to the investigations listed above for Northern England, and many other applications, there is still a need for testing its application with regard to the influence of human occupation on natural soils/sediments, the presence of animals or their links with occupation, the degree of evolution or maturity of materials, transfers of materials, pottery (descriptions and establishment of provenance), cave dwellings, burning/heating, climatic conditions, distinguishing between sediments and soil stratigraphy in archaeology, between colluvium and undisturbed soil, between disturbance caused by glacial, meteoric, animal or anthropogenic mixing, and between post-burial and pre-burial modifications, investigations on past agriculture and manuring.

Because of the intrinsic variability of soils and sediments, however, interpretative criteria obtained from testing micromorphological methods for certain soils and sites often can not be standardized or extrapolated to all other cases. Furthermore, as a result of the complex nature of soils and sediments, there can be other limitations to the applicability of micromorphology. For example, micromorphological features resulting from ancient depositional processes and/or past interactions between man, other organisms, environment, and time, are sometimes obliterated. Alternatively, environmental changes and inputs of materials often result in complex successions of soils and sediments, with some layers containing material that is not *in situ*. Thus, in one kind of material, in one sample or in one thin section, there can be features generated by different causes, during different time periods, and in different places.

In order to be diagnostic of past environmental and site conditions, soil features observed in thin section should logically correlate with a suitable model of the past environment and human occupation. This can be achieved by combining micromorphology with sufficient field work, and other parallel lines of evidence. Such an approach can help to test the micromorphological evidence reduce the number of thin sections necessary to represent a unit.

To substantiate the reliability of micromorphology in geoarchaeology, one possibility is to obtain information on the micromorphological forms resulting from various processes by carrying out experimental work simulating such processes, and monitoring the resulting micromorphological forms. Another way is to carry out micromorphological analysis of soils whose history is partly or largely known, correlating such history with the corresponding micromorphological features. A way to achieve this could be analysing micromorphological and other features of soils whose long and short-term management (for example agriculture) and environmental (for example rainfall or temperature) or other influencing factors have been recorded over many years in soil research stations or similar institutions, and preparing a summary of the various effects on soils and resulting macro- and micromorphological features.

It is also suggested that micromorphology could and should be used more to test the validity of other techniques, for example ^{14}C dating and pollen analysis (see Sections 1.4 and 2.17).

One of the problems met in the review of Chapter 1 has been that in some cases comments and interpretations on soils and sediments have been integrated into excavation reports without any data or reference to soil/sediment analysis or sources of information. However, though it is important to integrate soil data into archaeological reports, if soil data are not discussed or even shown, it is difficult to refer back to them or to understand which part of the archaeological report they refer to.

A limitation for the suitability of micromorphology can also be its 'colourful' or somehow mysterious jargon, which can assassinate even the best intentions of the most courageous reader. It is hoped that future works will reduce specialized terms to a minimum or will be complemented with simple short glossaries.

2.7 Clays

It has been observed (Canti, 1992) that human impact on clay translocation is harder to define than for any of the other major soil-forming processes. As shown by the many examples in Northern England, soils and sediments can be buried by other natural or anthropogenic soils or sediments and therefore clay translocation may occur after burial and affect buried horizons at different depths. This process, as well as the formation of stress clay features, is directly dependent on both palaeoenvironmental conditions or anthropogenic influences; and the arrangement of the resulting clay coating in soils and sediments mirrors the way such processes occurred. However, though studies on the time necessary for formation of clay coatings have been carried out (see Usai (forthcoming) Chapter 7), it is not clear how durable such coatings are once they have formed. The variety of evidence in this and other related topics highlights even more the need of more research on clay illuviation at archaeological sites.

The most useful method to observe and understand the processes of clay translocation is micromorphology accompanied by supporting evidence. As yet, however, very few experimental and descriptive studies have been made with respect to archaeological deposits. This is particularly the case in Northern England. Thus, significant amounts of research are needed to test the validity of the many hypotheses and postulates. Examples of possible research themes are establishing whether clay translocation is accelerated or affected by cultivation (see next Section 2.8); whether the presence of some chemical components, for example potassium or sodium, can affect the rate of translocation in archaeological deposits in the same way as they do in soils.

Great care is needed if clay coatings are used as palaeoclimatic markers. More experimental work must be carried out for different environmental and climatic conditions, and to establish the durability of clay products before we can be confident of the applicability of such features to specific case studies on archaeological sites.

2.8 Past agriculture and tools to investigate it

There is a need for a multidisciplinary approach when studying traces of evidence for agriculture in soils. Significant soil evidence for former cultivation is often represented by plough or spade marks (Smith, 1975; Carter and Davidson, 1998). Ard marks or ridge and furrow morphologies have often characterized ancient cultivated sites in Northern England (Keeley, 1979a, 1981; Macphail, 1982; Hall *et al.*, 1994; Usai, 1998). Other features, however, such as dusty silty coatings and any other features produced by translocation of silt or sand, have also been employed as diagnostic of past agriculture (Macphail, 1981; McHugh, 1987; 1993), though in some cases (see for example the study at Ferrybridge Henge: McHugh, 1993c) it was suggested that other factors could have caused them. More evidence is needed to explain how and to what extent such features can be employed to interpret past cultivation or other disturbance, and whether they can only be used as supporting rather than primary evidence. Experimental work could be of great help for answering such questions. This could include simulation of compression, ploughing, trampling and manuring on soils of different type and texture, and recording of the related features and their micromorphological appearance.

Suggested themes for research are:

- investigations of the effect of *modern* agriculture with *past* implements and methods on modern soils.
- description of the pedological and micromorphological evidence from soils at sites that were definitely cultivated in the past and/or of sites where the methods and duration of cultivation are known (not necessarily archaeological sites).
- study of the soil and micromorphological evidence from archaeological sites which have undergone cultivation during ancient times.
- analysing the micromorphology of soils whose management, including agriculture and manuring, has been recorded over many years by research stations or institutions.

2.9 Soil phosphorus in geoarchaeology

There have been only a few studies on soil phosphorus in Northern England (for example, Keeley, 1977a; Sheil *et al.*, 1993). These authors used soil phosphorus to identify human and animal wastes and anthropogenic contexts whose origin was not otherwise fully understood, whilst McHugh (1993; 1997) was able to infer the length of human activity and whether occupation was short/periodical or intensive.

The significance of phosphorus analyses in archaeology lies in the fact that much animal material left in soils is rich in phosphorus, thus contributing to interpretation of archaeological sequences of materials. It may allow, for example, the identification of cultural sites or the location of areas where animals were kept within certain settlements, or enable the practices of past manuring to be investigated. The amounts of phosphorus normally found in rocks and sediments, as well as the amounts found at different soil depths, have been described by various workers (See Usai (forthcoming) Chapter 7). Thus, human influence on the soils can be established when anomalies in the quantity of phosphorus are observed against an average value in the area or profile. Consideration must be given to the possible presence of phosphorus derived from modern fertilizers and losses depending on the characteristics of soil types. Although care is needed in interpreting the results obtained, they are widely considered in many cases to be sufficiently valid to enable geoarchaeological interpretations to be made.

Suggested research themes are:

- investigation of the changes in soil phosphorus with long- and short-term occupation in different soil types.
- monitoring a range of human intervention/influence on soils and their effect on phosphorus distribution in soils.

2.10 Soils, settlement site distribution: implications and further research

In Northern England, soils have all been classified into associations by the Soil Survey of England and Wales (1983 a and b). This classification covers all areas of the region, and classifies soils on the basis of their type, drainage and landscape position. A limitation, however, is the published scale of the maps at 1:250,000, which is too small to use for interpreting cultural features (e.g. palaeo-settlement distribution) in areas where changes occurred over very short distances, and are thus beyond the resolution of the available map. This problem can be overcome by obtaining further and more detailed information from other sources, including geological, topographical and pedological maps at a larger scale and, when necessary, by detailed site investigations and mapping of soils.

It is important that the information available from existing soil association classification and maps is exploited to the full. Thus, future research should include the establishment of relationships between soil types and archaeological settlements and preservation/decay in Northern England, employing the existing soil association maps in association with detailed site investigations.

2.11 The process of podsolization in relation to man

Chapter 7 discussed the different estimates that have been made of the duration of the process of podzolisation and how, podzolisation being a multivariate process, its speed clearly relates to the changes in the variables involved (Canti, 1992).

Different ages for podzols have been recorded, but the Neolithic and Bronze Age have been highlighted as the "major periods of transformation from brown earths to podzols" (*ibid.*), though it has also been emphasized that the fact that Bronze Age earthworks often bury podzols might not represent a causal relationship, and that there are also examples of post-Bronze Age podzols, brown podzolic and stagnopodzols. An important conclusion is that podzols can be either anthropogenic - as a result of clearance - or natural, without any human initiation.

Useful research could concern:

- the establishment of further evidence for podzols buried by datable archaeological material.

- preparation of a formal review of datable podzols records.

2.12 Sedimentary and soil organic matter

Buried organic matter is attacked by organisms. Various hypotheses could be tested on the mechanisms of modifications and changes involving organic matter in archaeological strata. It is suggested that more micromorphological evidence is needed on different types of humified or non-decomposed organic matter, including peat.

It has been shown that establishing the true age of soils (measured from the time when organic matter first started to accumulate) is rarely feasible because different humus fractions may have different ages whilst infiltration of humic acids and root penetration can cause inputs of carbon of different ages, in the same material. Radiocarbon dates tend to represent the age of the organic fractions present in the soil at the time of burial, but not the age of the burial event. Furthermore, not all organic fractions occurring at archaeological sites are derived from soil-forming processes. It is suggested that soil micromorphology can give considerable help in the identification of the extent of profile mixing and root penetration, which can cause carbon of different ages frequently to be added to the profile. Another, and in many cases more important recommendation is that different types of materials are taken from the same site and levels, and compared (Valentine and Dalrymple, 1975).

2.13 The 'dark earth'

Only very few studies on the urban 'dark earth' have been carried out in Northern England: Macphail (1980b) in excavations in York, and Macphail (1982) on layers from Chester. These studies did not include any micromorphology, but were based on measurements of organic carbon together with other chemical parameters, as well as phytolith and pollen analysis. It had previously been suggested that the dark earth formed from the slow decay of urban areas with, at first, fine debris accumulating alongside organic matter, and later the infilling and weathering of coarser debris, so that the dark earth could 'accrete' and form thick deposits, as the debris fill was 'expanded' by addition of organic matter and by increased porosity resulting from biological activity (Macphail, 1994). It was suggested that with time this could create calcareous brown earths and that, in the same way as in Berlin, rubble had produced a pararendzina over three decades, pedogenesis on some urban-Roman deposits could, too, produce a trend towards pararendzinas. Macphail and Courty *et al.* (1989) recommend more detailed studies of the dark earth, and suggested that micromorphological studies of dark earth should include sampling of underlying, adjacent and overlying deposits for comparison to aid the interpretation of particles within the dark earth itself. It is suggested that these and other studies are carried out in order to establish interpretative criteria, test their validity and obtain more evidence. Perhaps data on dark earth, including micromorphological information, should be collected whenever possible, when samples of dark earth become available, even if collecting such data is not immediately significant for the purpose of the particular excavation concerned. In this way an archive and reference information could be gathered until representative evidence is obtained and significant comparisons and correlations are possible.

2.14 Mineralogical studies

Most mineralogical studies in Northern England have been successful in the study of material provenance and site formation, especially through comparison with other representative material from local sites, answering the questions often asked by excavators and archaeologists: 'How did it get here? Where does this come from?'. The success of this type of study also depended on their combination of field work with a suite of other techniques. In particular, the example of Canti's (1992c) study at Flixborough showed the importance of mineralogical work in combination with chemical and physical analysis for investigations on preservation of organic materials. Thus, it is recommended that mineralogical studies supplement the suite of other techniques to be used in future research on preservation.

2.15 Hadrian's Wall

Soil investigations on Hadrian's Wall sites all have archaeological evidence for agriculture (plough marks, banks/ditches successions) pre-dating Roman features associated with the Wall (Section 1.11). This, together with the discussions in Usai (forthcoming) show the importance of two main fields of further research:

- investigation of past soil and environmental features of pre- or early-Roman periods through correlations of soil, sediments, pollen and biological evidence of sites through and about the Wall, including particularly investigations on past agricultural practices.

- employing the regional significance of such features related to pre- or early-Roman agriculture to establishing and recording the resulting forms in soils, particularly with micromorphological analysis. This will allow us to establish with more certainty what (if any) are the most important geoarchaeological/micromorphological features which can be correlated with such agricultural practices.

2.16 Alluvial and colluvial valley sedimentation

As illustrated in Section 1.12, studies on alluvial and colluvial valley sedimentation in Northern England have mainly been concerned with the Tyne basin. Their significance has been discussed in Section 1.12, and it is recommended that more studies concerned with valley sedimentation are carried out in the rest of Northern England.

2.17 Soil investigation including pollen analysis

The use of soil investigations together with pollen analysis has generally been successful (for example, Keeley, 1978; Macphail, 1988; McHugh, 1992; Canti and Weir, 1995). Though, for some sites, both soil and pollen investigations may have been carried out, only rarely (see references above) have the two disciplines been combined and the results correlated to produce interpretations.

Thus, it is important to carry out more studies where pedology and pollen analysis are combined, with soil and pollen sampling being carried out at the same time and on the same material, possibly employing the same or similar/correlatable sampling units.

2.18 Archaeology for pedology

Besides soil and sediment investigations being instrumental for archaeological interpretations, archaeological data can be irreplaceable for soil research, something which has largely been undervalued. In fact, this review shows that there is no evidence of any archaeological work in Northern England having been significantly employed for investigations concerned with sedimentology, pedology or other fields of earth science. As shown by the many examples of dated archaeological material burying soils, it is important that at least some of the large amount of archaeological information available is employed for this purpose.

It is often impossible to define the length/intensity of some soil-forming processes, such as aggregate formation, or clay or other particle translocation and, hence, to correlate processes with the resulting forms. For example, with regard to clays and aggregates, it has been described (Payton and Usai, 1994) how oriented clay with a particular morphology both within soil aggregates and adjacent to aggregate surfaces could have resulted from seasonal wetness inducing differential stress of the soil matrix through swelling/shrinking volume changes. It is possible that in a material, whether soil, sediment or any archaeological context, clay separations resulting from stress of the soil matrix will be more pronounced and more frequent in older soils that have undergone more prolonged and/or frequent and intensive shrinking and swelling, and thus the development of aggregates and stress clay features as well as the differentiation of soil fabric, can be proportional to the degree and time of soil development. Many other factors (for example pH, availability of clay, Eh, temperature and nature of the soil matrix), however, are involved. In so far as the degree of soil development, which is much dependent on the length of soil development and landsurface stability, is also expressed by the presence, type, frequency and size of stress clay features, it has also been suggested that they can provide some indication of the climatic change the sediment has experienced (Fedoroff *et al.*, 1990).

Archaeological sites often provide further sources of information and dating which permit the application of an absolute time scale to otherwise unquantifiable evidence. Archaeological information can, if dated sediments overlie soils, give the time scale for the length of soil-forming processes, so that these can be matched with features related to the degree of soil development. In these and similar cases, archaeological data on the time range and management/use of the materials can provide information on the relationships between soil/sediment changes and the resulting forms.

Thus, an important aim of future research should be the employment of archaeological information for pedological and palaeo-environmental studies.

2.19 Other remarks

Reading Chapter 1 and Table A.1, it is immediately clear that, though a very large number of studies have been carried out and tremendous efforts have been put into geoarchaeological investigations in Northern England, only few of these studies have led to publication in journals of academic, scientific or international acceptance. Most of these studies, therefore, are unlikely to be read widely, and will therefore have little impact on society and its understanding of the importance of the discipline for archaeology. The reasons for this can be probably found in the various discussions in this chapter, for example in the section describing the problems derived from the procedures adopted with rescue archaeology.

It is clear, however, that the effort English Heritage has committed to the works reviewed needs to be described in a widely accessible publication. Only in this way will it be able to affect the state of the art and direction of the scientific, archaeological and 'layman' communities.

To achieve this, the archaeological soil or sediment scientist will need, from the project outset, to give a stronger emphasis to the academic and scientific quality of analysis and report writing, and to allow sufficient time and facilities to produce reports suitable for publication.

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Macklin, M G and Lewin, J 1989 'Sediment transfer and transformation of an alluvial valley floor: the river South Tyne, Northumbria, UK' *Earth Surface Processes and Landforms* **14,** 233-246

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Macphail, R 1980b 'Soil report on the 'dark earth' from the Bedern excavation at York' *AML Report* **3061**

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Macphail, R 1981 'Soil report on Beeston Castle' *AML Report* **3565**

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Macphail, R 1982 'Soil report on Chester Princess St'. *AML Report* **3741**

Macphail, R 1983 'Soil from Beeston Castle' *AML Report* **4101**

Macphail, R 1983 'Soil from West Heslerton' *AML Report* **4088**

Macphail, R 1984 /Soil report on Beeston Castle'*AML Report* **4441**

Macphail, R 1986 'Soils' *in* Powlesland, D, Haughton, C and Hauson, J (ed) *Excavations at*

Heslerton, North Yorkshire (1978-82). Archaeological Journal **143**, 53-173.

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Macphail, R 1988 'Soil report on Beeston Castle, Cheshire' *AML Report New Series* **173/88**

Macphail, R 1991 'Second soil report on West Heslerton, near Malton, North Yorkshire: the cemetery excavation, area 2BB' *AML Report New Series* **91/91**

McHugh, M 1989a 'Soil report: Saddler Street, Durham' *AML Report New Series* **104/89**

McHugh, M 1989b 'Soil report: Tullie House, Carlisle, Cumbria' *AML Report New Series* **105/89**

McHugh, M 1989c 'Soil report: Crossgates Farm, Seamer, N Yorks' *AML Report New Series* **106/89**

McHugh, M 1992b 'Notes on soils from the Ravock field system above Deepdale in Western Co. Durham' *AML Report New Series* **85/92**

McHugh, M 1992a 'Soils, vegetation and landuse change in the Stainmore area of the Northern Pennines' *AML Report New Series* **45/92**

McHugh, M 1993c 'Ferrybridge Henge I, W Yorkshire: soils of the pit alignment and ditch, infill processes and landuse' *AML Report New Series* **61/93**

McHugh, M 1993a 'Mire development and spring activity at grange farm, Long Lane, Beverley' *AML Report New Series* **62/93**

McHugh, M 1993b 'St. Giles hospital, Brough St., Giles, N Yorkshire: soil characteristics and early human activity' *AML Report New Series* **60/93**

McHugh, M 1997 'Soils Analysis' *in* Cardwell, P, Speed, G, Huntley, J P, McHughs, M, Manby, T G and Wenban-Smith, F *Prehistoric occupation at St. Giles by Brompton Bridge, North Yorkshire. Durham Archaeological Journal* **12**, 27-40

Manby, T G and Wenban-Smith, F 1996 'Prehistoric occupation at St. Giles by Brompton Bridge, North Yorkshire'. *Durham Archaeological Journal* **12**, 27-40

Passmore, D and Macklin, M 1997 'Geoarchaeology of the Tyne basin: Holocene river valley environments and the archaeological record' *in* Tolan-Smith, C, Macklin, M, Passmore, D, Smith, J E and Tolan-Smith, M *Landscape archaeology in Tynedale.* Newcastle upon Tyne: Department of Archaeology, University of Newcastle

Passmore, D and Macklin, M G 1994 'Provenance of fine-grained alluvium and late-Holocene land-use change in the Tyne basin, Northern England' *Geomorphology* **9**, 127-142

Passmore, D G, Macklin, M G, Heap, T and Anderson, J 1991 'Geoarchaeological investigations of late Holocene alluvial fans and valley side sediments at Habitancun Roman Fort, West Woodburn, Northumberland: a re-evaluation of the *Piercebridge* formula'. *Universities of Durham and Newcastle upon Tyne Archaeological Reports* **14**, 29-32

Payton, R W and Usai, M-R 1995b 'Soils' *in* Lancaster University Archaeological Unit (ed) *Low Hauxley, Northumberland: archaeological evaluation.* Lancaster: Lancaster University Archaeological Unit

Payton, R W and Usai, M-R 1995a 'Assessment of soils and sediments from an exploratory excavation at Low Hauxley, Northumberland'*Reports from the Environmental Archaeology Unit,* **95/42**, 30pp

Rackham D J 1985 'Preliminary sampling exercise on a medieval and post-medieval midden, Lindisfarne'*AML Report* **4455**

Sheil, R, McHugh, M, Jones, M 1993 'Characteristics of garden soils, midden deposits, landfill and ballast material from Closegate 2, Newcastle-upon-Tyne' *AML Report New Series* **59/93**

Taylor, P 1978 'Monkgate, Hull: Soil report' *AML Report* **2443**

Tolan-Smith, C 1997b 'Chapter seven. The Stone Age landscape: the constribution of fieldwalking' *in* Tolan-Smith, C, Macklin, M, Passmore, D, Smith, J E and Tolan-Smith, M *Landscape archaeology in Tynedale.* Newcastle upon Tyne: Department of Archaeology, University of Newcastle

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Tolan-Smith, C, Macklin, M, Passmore, D, Smith, J E and Tolan-Smith, M 1997 *Landscape archaeology in Tynedale.* Newcastle upon Tyne: Department of Archaeology, University of Newcastle

Tolan-Smith, M 1997c 'The Romano-British and late prehistoric landscape: the reconstruction of a medieval landscape' *in* Tolan-Smith, C, Macklin, M, Passmore, D, Smith, J E and Tolan-Smith, M *Landscape archaeology in Tynedale.* Newcastle upon Tyne: Department of Archaeology, University of Newcastle

Usai, M-R 1994 'Assessment of thin sections of sediment samples from excavations at Withow Gap, Skipsea, Humberside (Site Code CAS 489)' *Reports from the Environmental Archaeology Unit,* **94/61**, 9pp

Usai, M-R 1995a 'Assessment of thin sections of soils and sediments from excavations at Thornbrough Farm, Catterick, North Yorkshire, sites CAS 452 (1990) and CAS 482 (1993)' *Reports from the Environmental Archaeology Unit,* **95/18**, 14pp

Usai, M-R 1995b 'The use of micromorphology in geoarchaeological studies' *in* Jaques, D and Kenward, HK (compilers) 'Research Forum (1995) Current and future research in the EAU. Abstracts from a one-day forum held in Derwent College, University of York, on 18th October

1995' *Reports from the Environmental Archaeology Unit,* **95/55**, pp 11

Usai, M- and Dalrymple, J B 1997 'Paleosol interpretation: case studies from Sardinia (Italy) and Northern England' *INQUA/ISSS Paleopedology Commission Newsletter* **14**

Usai, M-R 1998a 'Assessment of soil from Segedunum Roman Fort, Wallsend, North Tyneside' *Reports from the Environmental Archaeology Unit,* **98/13**

Usai, M-R 1998b 'Assessment of soils and sediments from Birdoswald Spur, Birdoswald Roman fort, Cumbria (site code CAS 5900)' *Reports from the Environmental Archaeology Unit,* **98/35**

Usai, M-R forthcoming 'Geoarchaeology in Northern England I: geography, soils and paleosols of the Northern region. ' *English Heritage: Centre for Archaeology Reports.*

Younger, P L and McHugh, M 1995 'Peat development, sand cones and palaeohydrology of a spring-fed mire in East Yorkshire, UK' *The Holocene* **5**, 59-67

Appendix 1. Geoarchaeological studies in Northern England

Table A.1a. Geoarchaeological studies in Northern England (1974-84). *Numbers in square brackets indicate AML report references.*

SITE/TOPIC	YEAR	AUTHOR	REFERENCE	NOTES AND KEYWORDS
Norton Priory, Runcorn, Cheshire	n.r.	n.r.	[1508]	General
Norton Priory, Runcorn, Cheshire	1974a	Keeley, H.C.M.	[1707; 36/74]	General
Catterick Bridge, North Yorkshire	1974b	Keeley, H.C.M.	[1708; 37/74]	General, with interpretation
Winterton, Humberside	1975a	Keeley, H.C.M.	[1886; 13/75]	General, descriptive
Winterton, Humberside	1975	Keeley, H.C.M.	[1937; 63/75]	Descriptive
Winterton, Humberside	1975	Keepax, C.A.	[1945; 72/75]	Descriptive
Wilderspool, Worrington Lanes, Lancashire	1977a	Keeley, H.C.M.	[2176; 2/77]	Descriptive; phosphorus investigation
Tarraby, Carlisle, Cumbria	1977b	Keeley, H.C.M.	[2228; 20/77]	Descriptive
Seamer Carr, North Yorkshire	1977a	Abrahams, P.	[2303; 44/77]	Descriptive with some interpretation
Kirkhead Caverrn, Cumbria	1977	Abrahams, P.	[2713; 45/77]	Phosphates; mapping; descriptive
Wharram Percy, North Yorkshire	1977	Abrahams, P.	[2360; 54/77]	Field work, geological and pedological mapping; soil classification
Seamer Carr, North Yorkshire	1977c	Keeley, H.C.M.	[2332; 47/77]	Descriptive with interpretations; references to P analysis
Hartlepool Bay, Cleveland	1978	Tooley, M.J.	*International Journal of nautical Archaeology and underwater exploration*, **7**, 71-75.	Reference to coast environment and local archaeology
Monkgate, Kingston-upon-Hull	1978	Taylor, P.	[2443; 1978]	Field descriptions
Norton Priory, Runcorn, Cheshire,	1978	Macphail, R. and Keeley, H.C.M.	[2701; 92/78]	Pollen study
Carlisle, Cumbria	1979a	Keeley, H.C.M.	[2887; 48/79]	Cultivation; descriptive
Barnard Castle, Durham	1979b	Keeley, H.C.M.	[2911; 62/79]	Descriptive

Callis Wold, Humberside	1979c	Keeley, H.C.M.	[2924; 66/79]	Descriptive
Keys Lane, Carlisle	1980a	Macphail, R.	[3058;1980]	Dark earth
Bedern, York	1980b	Macphail, R.	[3061;1980]	Dark earth
Hadrian's Wall, Lannerton Farm, Appletree, Cumbria	1980	Keeley, H.C.M.	[3101; 8/80]	Hadrian's Wall
Beeston Castle, Cheshire	1980c	Macphail, R.	[3235; 1980]	Beeston Castle
Throckley, Tyne and Wear	1981d	Keeley, H.C.M.	[3401; 16/81]	Hadrian's Wall
Beeston Castle, Cheshire	1981	Macphail, R.	[3565; 1981]	Beeston Castle
West Heslerton, N Yorkshire	1981	Macphail, R.	[3706; 1982]	Heslerton.
Princess Street, Chester	1982	Macphail, R.	[3741; 1982]	Dark earth
51 West Heslerton, Nr Malton, N Yorkshire	1983	Macphail, R.	[4088; 1983]	Heslerton
Throckley, Tyne and Wear	1983	Bennet, J., Keeley, H. and Miller, A.	Appendix: the pre-Wall soil and ard marks. *Archaeologia Aeliana,* **5**, XI.	Cultivation; Hadrian's Wall
Beeston Castle, Cheshire	1983	Macphail, R.	[4101; 1983]	Beeston Castle
Beeston Castle, Cheshire	1984	Macphail, R.	[4441; 1984]	Beeston Castle

Table A.1b. Geoarchaeological studies in Northern England (1984-1994). *Numbers in square brackets indicate AML report references.*

SITE/TOPIC	YEAR	AUTHOR	REFERENCE	NOTES AND KEYWORDS
Manor Farm, Borwick, Lancs	1985	Keeley, H.C.M.	[4480; 1/85]	Field and soil description
Lindisfarne	1985	Rackham, J.	[4455; 1985]	
Crosby on Eden, Cumbria	1985	Keeley, H.C.M.	[4631; 8/85]	Hadrian's Wall; descriptive
Heslerton, North Yorkshire	1986	Macphail, R.	Soils. In: Powlesland, D. , Haughton, C. and Hauson, J. (1986) Excavations at Heslerton, North Yorkshire 1978-82.*Archaeological Journal* **143**, 53-173.	Heslerton
Redfearns Glassworks, York	1987	Macphail, R.,	[112/87]	Soil micromorphology and interpretation of past cultivation
General Accident Extension, York	1987	Jones, A.K.J.	[148/87]	Descriptive
Beverley Eastgate, Humberside	1987	Evans, J.	[186/87]	Evidence for textile processing
Beeston Castle, Cheshire	1988	Macphail, R.	[173/88]	Soil micromorphology in relation to pollen and ^{14}C
Winterton Roman Villa, South Humberside	1988	Keeley, H.C.M.	[206/88]	Soil descriptions; pH, particle size analysis
Carlisle, Cumbria	1989	Keeley, H.C.M.	[48/89]	Soil descriptions; particle size analysis; geological/pedological descriptions; past agriculture
Ling Howe, Walkington, North Humberside	1989	Keeley, H.C.M.	[49/89]	Field work; some analytical work
Saddler Street, Durham	1989a	McHugh, M.	[104/89]	Field work and interpretation
Tullie House, Carlisle, Cumbria.	1989b	McHugh, M.	[105/89]	Field work and profile descriptions
Crossgate Farm, Seamer, N Yorkshire	1989c	McHugh, M.	[106/89]	Field work and interpretation

Little Ouseburn Barrow, North Yorkshire.	1989	Evans, J. and Biek, L.	Soils and deposits. In: Rahtz, P., Biek, L., Edwards, G., Evans, J., gaunt, G., Henderson, J., Jacobi, R., Keeley, H.C.M., Price, J. and Wilthew, P. (1989) *Little Ouseburn barrow 1958. York University Archaeological Publications 7.* York: Department of Archaeology, Unviersity of York.	Descriptive
River South Tyne, Northumberland	1989	Macklin, M.G. and Lewin, J.	Sediment transfer and transformation of an alluvial valley floor: the river South Tyne, Northumbria, U.K. *Earth Surface Processes and Landforms,* **14**, 233-246.	Colluvial/alluvial valley sedimentation
Eastgate, Beverley, North Humberside	1990	Heyworth, P.	[60/90]	Mineralogy; XR diffraction, XR fluorescence; infrared spectroscopy
Watertower St, Chester,	1990	Canti, M.G.	[130/90]	Mineralogy; heavy metals and particle size analysis; investigation on rampart blocks
Collingham, West Yorkshire	1991a	Canti, M.G.	[53/91]	Micromorphology; particle size and heavy metal analysis; Iron Age ditch fill
Brodsworth Hall, South Yorkshire	1991b	Canti, M.G.	[88/91]	Micromorphology; particle size and heavy mineral analysis
West Heslerton, near Malton , North Yorkshire,	1991	Macphail, R.	[91/91]	Particle size, calcium carbonate, pH, magnetic susceptibility and loss on ignition analysis

Garton-on-the-Wolds, Humberside	1991	Limbrey, S.	Limbrey, S. (1991) Deposition of clay in the Garton Station cart burial. In: Stead, I.M., Ambers, J., Clark, A.J., Crowfoot, E., Fell, V., Freestone, I.C. Greig, J.R.A., Henderson, J., Kinnes, I.A., Leese, M., Legge, A.J., Limbrey, S., Middleton, A.P., Pacitto, A.L., Rigby, V., Shearman, F., Stead, S., Thew, N., Wagner, P. And Watson, J. *Iron Age cementeries in East Yorkshire. Excavations at Burton Fleming, Rudston, Garton on the Wolds, and Kirburn.* English Heritage Archaeological Report No 22. English Heritage in Association with British Museum Press.	Soil micromorpholgy and particle size analysis of material replacing decayed wood.
Callaly Moor, Northumberland	1991	Macklin, M.G., Passmore, D.G., Stevenson, A.C., Cowley, D.C., Edwards, D.N. and O'Brien, C.F.	Holocene alluviation and land use change on Callaly Moor, Northumberland, England. *Journal of Quaternary Science*, **6** (3), 225-232.	Colluvial/alluvial valley sedimentation
Habitancun Roman Fort, West Woodburn, Northumberland	1991	Passmore, D.G., Macklin, M.G., Heap, T. And Anderson, J.	Geoarchaeological investigations of late Holocene alluvial fans and valley side sediments at Habitancun Roman Fort, West Woodburn, Northumberland: a re-evaluation of the *Piercebridge* formula. *Universities of Durham and Newcastle upon Tyne* Archaeological Reports, **14**, 29-32.	Colluvial/alluvial valley sedimentation
Stainmore, Northern Pennines	1992a	McHugh, M.	[45/92]	Soil survey, mapping, classification; particle size, chemical, mineralogical and micromorphological. analysis; radiocarbon dating
Flixborough, Humberside	1992c	Canti, M.G.	[53/92]	Particle size and mineralogical analysis; pH. Exceptional bone preservation

Ravock, Deep Dale, Durham	1992b	McHugh, M.	[85/92]	Soil survey, mapping, classification; particle size, chemical, mineralogical and micromorphological. analysis; radiocarbon dating
Closegate 2, Newcastle-upon-Tyne	1993	Sheil. R., McHugh, M., Jones M	[59/93]	Phosphorus analysis; 13th-17th century
Grange Farm, Long Lane, Beverley	1993a	McHugh, M.	[62/93]	Micromorphological, mineralogical, C and N analysis. Sand cones within peat (2090-1170 BP)
Various sites in Northern England	1993b	Canti, M.G.	[42/93]	Review
St.Giles Hosp., Brough St. Giles, North Yorkshire	1993b	McHugh, M.	[60/93]	Micromorphology; site forming processes; phosphorus analysis
Ferribridge Henge I, West Yorkshire	1993c	McHugh, M.	[61/93]	Micromorphology; site forming processes; past agriculture
Withow Gap, Skipsea, Humberside	1994	Usai, M.-R.	Assessment of thin sections of sediment samples from excavations at Withow Gap, Skipsea, Humberside (Site Code CAS 489). *Reports from the Environmental Archaeology Unit*, **94/61**, 9pp.	Micromorphology of sediments, soils and gyttja
Stanwix, Carlisle, Cumbria	1994	Hall, A., Kenward, H.K., Large, F. And Usai, M.-R.	Assessment of biological remains and sediments from Roman deposits at Cumbria College of Art, Stanwix, Carlisle (site code ARC94). *Reports from the Environmental Archaeology Unit*, **94/57**, 7pp.	Pedological and biological analysis
Tyne Basin, Northumberland	1994	Passmore, D. and Macklin, M.G.	Provenance of fine-grained alluvium and late-Holocene land-use change in the Tyne basin, Northern England. *Geomorphology* **9**, 127-142.	Alluvial/colluvial valley sedimentation

Table A.1c. Geoarchaeological studies in Northern England (1995-1998). *Numbers in square brackets indicate AML report references.*

SITE/TOPIC	YEAR	AUTHOR	REFERENCE	NOTES AND KEYWORDS
Magistrates Court, Kingston-upon-Hull	1995	Carrott, J., Dobney, K., Hall, A., Irving, B., Issit, M., Jaques, D., Kenward, H.K., Large, F., McKenna, B., Milles, A.,Shaw, T. and Usai, M.-R.	Assessment of biological remains and sediments from excavations at the Magistrates' Court site, Hull (site code: HMC94). *Reports from the Environmental Archaeology Unit,* **95/17**, 17pp.	Soil sampling; major biological analysis. Assessment
Thornbrough Farm, Catterick, North Yorkshire	1995a	Usai, M.-R.	Assessment of thin sections of soils and sediments from excavations at Thornbrough Farm, Catterick, North Yorkshire, sites CAS 452 (1990) and CAS 482 (1993). *Reports from the Environmental Archaeology Unit,* **95/18**, 14pp.	Soil micromorphology. Assessment
Low Hauxley, Northumberland	1995a	Payton, R.W. and Usai, M.-R.	Assessment of soils and sediments from an exploratory excavation at Low Hauxley, Northumberland. *Reports from the Environmental Archaeology Unit,* **95/42**, 30pp	Field work, profile and sample description; soil micromorphology. Paleosols with prehistoric archaeology. Assessment
Low Hauxley, Northumberland	1995b	Payton, R.W. and Usai, M.-R.	Soils. In: Lancaster University Archaeological Unit (Ed.) *Low Hauxley, Northumberland: archaeological evaluation.* Lancaster: Lancaster University Archaeological Unit.	Field work, profile and sample description; soil micromorphology. Paleosols with prehistoric archaeology.
Soil micromorphology in archaeology	1995b	Usai, M.-R.	The use of micromorphology in geoarchaeological studies. In: Jaques, D. And Kenward, H.K. (Compilers) (1995) Research Forum1995: Current and future research in the EAU. Abstracts from a one-day forum held in Derwent College, University of York, on 18th October 1995. *Reports from the Environmental Archaeology Unit,* **95/55**, pp 11.	Soil micromorphology. Not site based

Belmont Moated, Great Budworth, Cheshire	1995	Canti, M.G. & Weir,D.	[45/95]	Soil/sediment cores; pollen analysis
Town Wall in the Milk Market, Newcastle Upon Tyne	1995	Johnson,G.A.L.	Geological analysis of gravel from below the wall foundation In: Heslop. D.H., Truman, L. And Vaugham, J.E. Excavation of the Town Wall in the Milk Market, Newcastle Upon Tyne. *Archaeologia Aeliana*, **23**, 233.	Soil description
Beverley, East Yorkshire	1995	Younger, P.L. and McHugh, M.	Peat development, sand cones and palaeohydrology of a spring-fed mire in East Yorkshire, UK. *The Holocene*, **5 (1)**, 59-67.	Micromorphological, mineralogical, C, N and hydraulic conductivity analysis. Sand cones within peat (2090-1170 BP)
York	1996	Jaques, D., Kenward, H.K. and Usai, M.-R.	An evaluation of vertebrate remains and sediments from excavations at St Mary's Abbey Precint Wall, York (Site code 96.168). *Reports from the Environmental Archaeology Unit*, **96/21**, 4pp.	Soil sediment description
Northern England and Sardinia	1997	Usai, M.-R. and Dalrymple, J.B.	Paleosol interpretation: case studies from Sardinia (Italy) and Northern England. *INQUA/ISSS Paleopedology Commission Newsletter 14*.	Paleosol investigation methods; soil micromorphology
St. Giles by Brompton Bridge, North Yorkshire	1997	McHugh, M.	Soils Analysis. In: Cardwell, P., Speed, G., Huntley, J.P., McHughs, M., Manby, T.G. and Wenban-Smith, F. (1996) Prehistoric occupation at St. Giles by Brompton Bridge, North Yorkshire. *Durham Archaeological journal* **12**, 27-40.	Site forming processes; soil phosphorus analysis

Tyne Basin, Northumberland	1997	Passmore, D. and Macklin, M.	Geoarchaeology of the Tyne basin: Holocene river valley environments and the archaeological record. In: Tolan-Smith, C., Macklin, M., Passmore, D., Smith, J.E. and Tolan-Smith, M. (1997) *Landscape archaeology in Tynedale*. Newcastle upon Tyne: Department of Archaeology, University of Newcastle.	Alluvial/colluvial valley sedimentation
Tynedale.	1997	Tolan-Smith, C., Macklin, M., Passmore, D., Smith, J.E. and Tolan-Smith, M.	*Landscape archaeology in Tynedale.* Newcastle upon Tyne: Department of Archaeology, University of Newcastle.	Alluvial/colluvial valley sedimentation. Collection of papers, not all site based.
Landscape archaeology. Tynedale.	1997	Tolan-Smith, C.	(1997a) Chapter one. Landscape Archaeology. In: Tolan-Smith, C., Macklin, M., Passmore, D., Smith, J.E. and Tolan-Smith, M. (1997) *Landscape archaeology in Tynedale,* 1-10. Newcastle upon Tyne: Department of Archaeology, University of Newcastle	Alluvial/colluvial valley sedimentation. Not site based.
Stone age landscape. Tynedale.	1997	Tolan-Smith, C.	(1997b) Chapter seven. The Stone Age landscape: the constribution of fieldwalking. In: Tolan-Smith, C., Macklin, M., Passmore, D., Smith, J.E. and Tolan-Smith, M. (1997) *Landscape archaeology in Tynedale,* 79-89. Newcastle upon Tyne: Department of Archaeology, University of Newcastle.	Alluvial/colluvial valley sedimentation. Not site based.

Romano-British and late prehistoric landscape. Tynedale.	1997	Tolan-Smith, M.	(1997c) The Romano-British and late prehistoric landscape: the reconstruction of a medieval landscape. In: Tolan-Smith, C., Macklin, M., Passmore, D., Smith, J.E. and Tolan-Smith, M. (1997) *Landscape archaeology in Tynedale*,69-78. Newcastle upon Tyne: Department of Archaeology, University of Newcastle.	Alluvial/colluvial valley sedimentation. Not site based.
Wallsend, North Tyneside	1998	Usai, M.-R.	Assessment of soil from Segedunum Roman Fort, Wallsend, North Tyneside. *Reports from the Environmental Archaeology Unit*, **98/13**.	Field work. Evaluation.
Birdoswald, Cumbria	1998	Usai, M.-R.	Assessment of soils and sediments from Birdoswald Spur, Birdoswald Roman fort, Cumbria (site code CAS 590). *Reports from the Environmental Archaeology Unit*, **98/35**.	Field work. Assessment.
York and Yorkshire	2000	Kenward, H.K. and Hall, A.H.	Decay of delicate organic remains in shallow urban deposits: are we at a *watershed? Antiquity*, **74**, 519-525	Critical review and summary of findings, based on site evidence in Yorkshire.
Non site-based	2000	Canti, M.G. and Linford, N	The Effects of Fire on Archaeological Soils and Sediments: Temperature and Colour Relationships. *Proceedings of the Prehistoric Society* **66**	Experimental reproduction of burning conditions similar to those of ancient hearths and observations on soil reddening