PALEOPEDOLOGY IN ARCHEOLOGY

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Summary
Soils are a significant part of the physical landscape that supports a culture: they form the ground surface, they are a source of food, they reflect the environment and record the passage of time, and they can record the impact of human occupation. Soils have been recognized as important components of archeological sites and the archeological record for many decades and the principals of pedology and soil geomorphology, including both field and laboratory investigations, have had wide application in archeological research. In North America, most soil studies in archeological contexts concentrate on soils as stratigraphic markers and as age and paleoenvironmental indicators. Similar geoaarcheological applications of paleopedology have been conducted in the loess-rich areas of Europe and Asia, and at many of the well-known fossil hominid localities in East Africa. Elsewhere in Europe, most notably in Great Britain, the research emphasis tends to be on the use of soils as indicators of landuse, particularly agriculture, as well as indicators of paleoenvironments. Soils, and especially soil chemistry, have also been important in archeological research focused on agriculture in Central and South America.

1 Introduction
Soils are an obvious and integral part of most natural landscapes and are therefore a component of cultural landscapes. They are not just a backdrop to human occupation, however; they are indicators of the surface that physically supports a culture, they are a source of food, they reflect the environment and record the passage of time, and they record evidence of the nature and impact of human occupation. Soils are, therefore, a potential source of much information in archeological studies at site- and feature-specific scales as well as regionally. This paper is a review of how the study of soils, specifically the principles of pedology and soil geomorphology, have been applied in archeological and geoaarcheological research. It is not exhaustive; instead examples are drawn from various sources and regions.

Paleopedology is defined as the study of paleosols (RUHE 1965), but the term "paleosol" is defined in a variety of ways and none is satisfactory (FENWICK 1985, CATT 1986, HOLLIDAY 1989a). Definitions for paleosols include:
- soils of obvious antiquity (MORRISON 1967, 10);
- ancient soils (BUTZER 1971, 170);
- soils formed on a landscape of the past (RUHE 1965, 755, YAALON 1971, 29) or under an environment of the past
(YAALON 1983);
- or as soils formed under conditions generally different from those of today (PLAISANCE & CAILLEUX 1981, 702).

In these definitions, exactly what constitutes a preexisting or past landscape or past environment or how old the soil has to be are never defined. The argument could be made that all soils are paleosols, making the term redundant, because landscapes are always being subjected to some modification and the environment is never static, and because all soils take some time to form. Following on the above consideration and the arguments of CATT (1979, 1986) and KEMP (1985), among others, the preference here is simply to use the term soil.

Soil studies of one kind or another have long been recognized as valuable in archaeological research, if for no other reason than that soils often enclose or underlie the cultural debris in question. The available literature on the subject indicates that most research concerning soils in archeological contexts has taken place in North America and Europe, especially Great Britain, and the approaches taken to this research appear to vary considerably depending on where the work was done. Many of the North American studies focus on soils as stratigraphic markers and age and paleoenvironmental indicators, as is the case in the loess-rich areas of Europe. Outside these areas in Europe, however, and most notably in Great Britain, the research emphasis tends to be on the use of soils as indicators of human impact or human paleoenvironments.

This regional variation in the use of soils in archeology is probably a result of differences in the nature of archeological records in the two regions and in the history of geoarchaeological research in each. In North America, archeological sites with long records of human occupation in thick, well-stratified deposits with intercalated buried soils are relatively common, especially in the central and western regions. The impact of prehistoric peoples on soils and on the landscape was minimal, however. This is essentially the reverse of the situation in many areas of Europe, where archeological sites in thick stratigraphic sequences are little known (probably because such sites are older and less well preserved or less visible), but human beings have exerted a profound impact on the landscape for thousands of years. This is apparent in the comprehensive works of CORNWALL (1958) and LIMBREY (1975) and in the papers assembled by GROENMAN-VAN WATERINGEN & ROBINSON (1988). The following discussion reviews these different approaches to archeological pedology, including the use of soils as stratigraphic markers, age indicators, and paleoenvironmental indicators, and soils as indicators of the impact of people on the landscape. Most but not all of the examples come from North America and Europe.

2 Soils as stratigraphic markers and paleoenvironmental indicators

Probably the earliest use of soils in archeology was as stratigraphic markers. This apparently was for several reasons. Pedologic features, most notably soil horizons, are often the most prominent features in stratified deposits. Furthermore, much of the early archeological pedology was done by individuals trained in Qua-
ternary geology, where soils have long been recognized as stratigraphically important (VALENTINE & DALRYMPLE 1976). The environmental significance of soils in archeological research also probably has its roots in Quaternary geology, although the nature of prehistoric environments has also long been a fundamental question in archeology.

### 2.1 North America

The early use of soils as stratigraphic markers and paleoenvironmental indicators in archeological research is best exemplified by the work of BRYAN (1941a), the eminent geomorphologist. At Sandia Cave, New Mexico, he used compound pedologic features (illuvial iron, aluminium, and clay along with secondary carbonate) to infer a shift from a more humid environment (favouring development of "pedalfers") to a drier one (favouring development of "pedocals").

BRYAN (1941b, c) also defined a so-called "alluvial chronology", based upon supposed synchrony of late-Quaternary depositional events throughout the southwestern United States. The alluvial chronology was used for, among other purposes, correlation of archeological remains, and one aspect of this geological record was the presence of soils. Many investigators working in the west defined similar kinds of stratigraphic sequences, often for archeological purposes and also often including soils. For example, working in the Davis Mountains area of far western Texas, ALBRITTON & BRYAN (1939) identified buried A-horizons as guides for finding occupation zones. This geoarchaeological research led to one of the earliest comprehensive discussions of buried soils as potential environmental indicators in the western United States (BRYAN & ALBRITTON 1943).

In the southwest the work of BRYAN and others culminated with the definition of the classic western late-Quaternary alluvial chronology of HAYNES (1968), based in part on data from archeological sites and subsequently applied in geoarchaeological research (e.g. HAYNES 1971, 1975, JOHNSON 1974). Buried soils are essential elements in the definition and identification of several of HAYNES's depositional units. Clearly soils are important as stratigraphic markers in geoarchaeological research in the southwest and continue to be so recognized (e.g. WATERS 1986), although it is now apparent that an alluvial chronology is difficult to apply regionally (e.g. KNOX 1983, WATERS 1985).

In the southwestern United States there are few examples of using soils for dating archeological sites. One of these is the controversial Calico site in the Mojave Desert of California. The artificial status of material recovered from this locality remains to be shown and widely accepted, but soil-geomorphic research and comparisons with soil-geomorphic data from elsewhere in the region (BISCHOFF et al. 1981) clearly shows the site to be at least 80,000 years old. The soil age is confirmed by an associated uranium-series date of about 200,000 yr B.P. from groundwater carbonate at the site.

Soils have been widely employed in geoarchaeological investigations throughout the Great Plains and adjacent regions of North America. On the Southern High Plains of northwestern Texas and eastern New Mexico buried soils are prominent features of late-Quaternary valley fills and have been used in geoarchaeological research. Buried soils
were recognized at the Lubbock Lake site as early as 1939 (WHEAT 1974) and have proved to be especially useful in defining the stratigraphical record at that locality (JOHNSON 1974, STAFFORD 1981, HOLLIDAY 1985a,b,c), as well as other sites (HAYNES 1975, HOLLIDAY 1985d, MELTZER & COLLINS 1987), and in making correlations between the sites (HOLLIDAY 1985d, 1986, 1989b, HILL & MELTZER 1987) (fig.1). The exceptional age-control at Lubbock Lake allows relatively precise dating and estimation of the rates of development of the soils and of pedological features such as argillic and calcic horizons. This information has proved useful in dating deposits at other archeological sites in the region (HOLLIDAY 1986, 1989b).

Buried soils are also significant as paleoenvironmental indicators at archeological sites on the Southern High Plains. At Lubbock Lake, early Holocene buried soils high in organic matter and often with mottles and gley colours indicate marshy conditions due to a high water
table; they also suggest a dramatic pedochemical change in the mid-Holocene that was probably climatically induced (HOLLIDAY 1985b). Similar early-Holocene marsh soils are recognized at the famous Clovis site (Blackwater Draw Locality 1) (HAYNES 1975).

Recognition of buried soils and consideration of sedimentation rates versus rates of pedogenesis play an important role in recovering and interpreting the archeological record of the Rolling Plains of northcentral Texas and central Oklahoma (FERRING 1986, FERRING & PETER 1987). There apparently were several regional episodes of rapid sedimentation followed by periods of landscape stability and soil formation over the past two millennia. Artifact densities and site preservation potential are affected by the varying rates of sedimentation: sites on the stable surfaces (associated with buried soils) are more likely to have higher artifact densities and to be modified by the effects of pedoturbation and bioturbation.

In Wyoming REIDER (1980, 1982a, b) has used soils for environmental reconstructions at a number of archeological sites. Latest-Pleistocene and early-Holocene buried soils indicate high water table conditions (high organic matter content and grayish mottling). Younger soils in overlying sediments are typically well-drained, suggesting a lowered water table. These data are taken to indicate a climatic shift from moist conditions (late Pleistocene) to a reduction in effective precipitation (middle Holocene).

There are a few examples from the northern Great Plains dealing with archeological pedology. In the Missouri River badlands of North Dakota JORSTAD et al. (1986) identified a number of buried soils at archeological sites with thick deposits of eolian sand and silt. The soils and sediments indicate that throughout the Holocene there were cycles of eolian deposition in the area, the result of drought (CLAYTON et al. 1976), separated by periods of non-deposition and soil formation, representing moister conditions (CLAYTON et al. 1976). This is a significant aspect of the regional, Holocene landscape evolution as it pertains to the archeology of the area in that it allows for the superposition of the remains of sequential occupations. Elsewhere in North Dakota, KUEHN et al. (1987) used soils and other data to reconstruct the mid-Holocene environmental history and landscape evolution of the Tysver-Olson site. Burial of a soil in the middle-Holocene and development of a late-Holocene soil in the covering sediment are taken to indicate a period of considerable erosion and redeposition of material due to mid-Holocene aridity. To the northwest, along the Rocky Mountain foothills of Alberta, REEVES & DORMAAR (1972) examined several buried soils exposed at an archeological site near the forest/grassland ecotone. Physical and chemical characteristics of the soils, in particular the infrared absorption spectra of the humic acids, indicated that the forest/grassland boundary moved across the site twice in response to Holocene climatic changes; from forest to grassland in the early Holocene and back to forest in the mid-Holocene.

A buried soil in a core from the continental shelf of western Canada may have significant archeological implications (LUTERNAUER et al. 1989). The soil, dated to ca. 10,500 yr B.P., shows that the shelf was subaerially exposed in the latest Pleistocene, probably because the area was on the forebulge of
the Cordilleran ice sheet. The authors conclude that large areas of the shelf of western Canada were exposed above sea level, therefore "providing extensive low-relief terrain suitable for occupation by humans migrating southward from Beringia" (LUTERNAUER et al. 1989, 360). This conclusion supports the argument by FLADMARK (1979) that the initial migration of people from Asia into North America may have followed the North Pacific coast, in contrast to the traditional view that the migration was through a mid-continental "ice-free corridor".

In the midwestern United States buried soils have been recognized for decades as important components of Quaternary stratigraphy and as paleoenvironmental indicators. For example, one of the best-known soil-stratigraphic units in the world, the Sangamon Soil, was identified as a significant stratigraphic marker in loess and till sequences in the 1870s (FOLLMER 1978). Geoarcheologists in the midwest are also making use of soils in their research. Considerable geoarcheological effort has focused on the Lower Illinois River valley in southwestern Illinois, primarily at the Koster and Napoleon Hollow sites (BROWN & VIERRA 1983, WIANT et al. 1983), which are in fans located near tributary mouths at the base of bluffs bordering the Illinois River valley. Buried soils were useful in correlating site stratigraphy, but more importantly they indicate periods of landscape stability during formation of the fans — an important aspect of the evolution of the Holocene landscapes inhabited by the prehistoric occupants. This has important implications for site formation and preservation processes.

Geoarcheological studies similar to those in Illinois have been carried out in Iowa. At the Cherokee Sewer site, HOYER (1980) identified eighteen stratigraphically significant buried Holocene soils associated with archeological materials in an alluvial fan, which was apparently a favoured hunting locality between 10,000 and 4,600 yr B.P. The weakly developed soils (A-C and A-Bw profiles) denote episodic accretion of the fan, with only short intervals of non-deposition and human occupation. In the Missouri River drainage of western Iowa THOMPSON & BETTIS (1980) used buried soils for regional stratigraphic correlations of late Quaternary deposits and as indicators of stable landscapes in order to predict the location of buried archeological sites.

2.2 Europe

In Europe some of the best examples of using soils for stratigraphic and paleoenvironmental interpretations, in both archeological and non-archeological studies, come from the areas of thick loess deposits. KUKLA (1975, 1977) conducted landmark studies relating loess deposition and soil formation to Quaternary climatic changes, building on considerable earlier research on the sequence of loesses and buried soils. HOFFECKER (1987) presents a useful summary of these investigations and uses the upper Pleistocene loess record of Central Europe to establish the chronology of the Paleolithic record found in loess on the Russian Plain (fig.2). Buried soils are used as marker beds for correlation and also for comparing paleoenvironmental conditions in each area. The results point to significant differences in the timing and distribution of Paleolithic settlement between
Fig. 2: Correlation chart of Paleolithic site stratigraphies from the Russian Plain proposed by HOF-FECKER (1987, Figure 6; reproduced from Geoarchaeology: An International Journal, 1987, 2, 259–284, copyright by John Wiley & Sons, Inc.). These correlations are based largely on the buried soils present at the various sites (a, Molodova V; b, Molodova I; c, Korman'IV; d, Ataki I; e, Kestrosy; f, Kulichivka).
2.3 Asia, The Middle East and Africa

The spectacular loess sequences of Asia also contain evidence of human occupation, though English-language accounts of soil/archaeological studies are few; DODONOV (1987) lists some of the pertinent literature in Russian. One available example is from a large-scale research project in Soviet Central Asia (RANOVA & DAVIS 1979, DAVIS et al. 1980). Several sites in the region yielded evidence of Paleolithic occupations associated with soils buried in the loess. The soils are used as stratigraphic markers, for correlation and also as paleoclimatic indicators. The data indicate that the soils formed under conditions similar to those of today in the area (a semiarid steppe) and that the loess accumulated under cooler, drier conditions. Similar paleoenvironmental interpretations are made for two middle-Pleistocene sites in central China, where hominin ("Lantian Man") bone was recovered from loess (ZHISHENG et al. 1987). Buried soils in the loess were also used for dating and correlation between the sites.

Buried soils are also common in volcanic deposits in Japan. At the Yagi site, on the island of Hokkaido, STIMMELL et al. (1984) discuss a series of buried Holocene soils formed in volcanic ash and associated with Initial to Early Jomon period (9000-5000 yr B.P.) occupations. Samples from the site were analysed by various physical and chemical methods to help confirm the field stratigraphic designations and to determine the age and origin of the volcanic sediments, which form the substrate of the occupation zones.

Soils have proved useful in geoarchaeological studies throughout the Middle East. GOLDBERG (1986) used
them to correlate stratigraphic sequences throughout the northern Sinai and northwestern Negev. Geological data were used to reconstruct the Quaternary environments in an area rich in Paleolith and later archeological remains. GOLDBERG (1987) also studied micromorphology at the Berekhat Ram site in the Golan Heights to establish the origin of a "red clay layer" associated with Acheulian artifacts and previously assumed to be simply a buried soil. The results showed that the zone had a much more complex depositional and diagenetic history, being composed of two sedimentary units modified by both pedogenic and groundwater activity. HENRY et al. (1983) carried out a regional archeological study in southern Jordan and used soils and other geological evidence to reconstruct the late-Quaternary environmental history of the region. Pedological features such as carbonate accumulation and rubefication were used as climatic indicators.

Geoarchaeology has been an important part of archeological research in the eastern Sahara, beginning with the Aswan dam and reservoir project (CLOSE 1987) and focusing on the Nile valley and the Western Desert of Egypt and the northern Sudan. Pleistocene and Holocene buried soils were identified throughout the region and used largely as stratigraphic markers, although they also provided some paleoenvironmental data (arid conditions indicated by degree of leaching and accumulation of carbonates and salts) and data for reconstructing the landscape evolution of the region (e.g. BUTZER & HANSEN 1968, WENDORF & SCHILD 1976, 1980, PAULISSEN & VERMEERSCH 1987).

BUTZER (1981) used soil morphology and soil stratigraphy in a geoarcheological reconstruction of the rise and fall of the civilization of Axum, Ethiopia, during the last two millennia. Buried soils provided evidence for cycles of landscape stability, erosion, and aggradation, resulting largely from environmental changes and cultural impacts, which profoundly affected the economic history of the area.

Soils have been utilized in geoarchaeological studies at the many important hominid localities in southern and eastern Africa. BUTZER (1974) used pedogenic phenomena to reconstruct the paleoenvironmental histories of two achenelian (middle Pleistocene) sites in South Africa with complex depositional and hydrological records. Calcretes suggested semiarid conditions similar to those of the present and decalcification and rubefication indicated moister climatic conditions. In a review of the geoarchaeology and Quaternary environments in South Africa, BUTZER (1984) used soils data to date and correlate a number of sites and to indicate landscape evolution during occupation.

Buried soils are preserved in the thick sedimentary sequences at many of the famous hominid localities in the East African Rift area (e.g., HAY 1976, BISHOP et al. 1978). RETALLACK (1986, 39–40) summarizes some of the pedological records and presents some paleoenvironmental reconstructions of the alluvial uplands and alkaline-lake margins at Olduvai Gorge, based on field morphologies of the soils. For example, weakly developed buried soils with zeolites are interpreted as "alkaline Entisol supporting scrubby, salt tolerant vegetation" and "dark granular paleosols with calcareous subsurface layers . . . may have been Molisols, formed under grassland and savannah" (RETA-
<table>
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<th><strong>Beneficial</strong> effects*</th>
<th><strong>Detrimental</strong> effects*</th>
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<tbody>
<tr>
<td>1. Parent Material</td>
<td>(a) Adding mineral fertilizers; (b) accumulating shells and bones; (c) accumulating ash locally; (d) removing excessive amounts of substances such as salts (e) marling; (f) warping</td>
<td>(a) Removing through harvest more plant and animal nutrients than are replaced; (b) adding materials in amounts toxic to plants or animal nutrients than are replaced (c) altering soil constituents in a way to depress plant growth.</td>
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<td>2. Topography</td>
<td>(a) Checking erosion through surface roughening, land forming, and structure building; (b) raising land level by accumulation of material; (c) land levelling</td>
<td>(a) Causing subsidence by drainage of wetlands and by mining (b) accelerating erosion (c) excavating</td>
</tr>
<tr>
<td>3. Climate</td>
<td>(a) Additional water by irrigation; (b) rain-making by 'seedling' clouds; (c) release of CO₂ to atmosphere by industrial man, with possible warming trend in climatic (d) heating air near the ground; (e) subsurface warming of soil, electrically or by piped heat; (f) changing colour of surface of soil to change albedo (g) removing water by drainage; (h) diverting winds</td>
<td>(a) Subjecting soil to excessive insolation, to extend frost action, to exposure to wind, to compaction; (b) altering aspect by land forming; (c) creating smog; (d) clearing and burning off organic matter</td>
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<td>4. Organisms</td>
<td>(a) Introducing and controlling populations of plants and animals (b) adding organic matter (including 'nightsoil') to soil directly or indirectly through organisms; (c) loosening soil by ploughing to admit more oxygen; pathogenic organisms, as by controlled burning</td>
<td>(a) Removing plants and animals; (b) reducing organic matter content of soil through burning, ploughing, overgrazing, harvesting, accelerating oxidation, leaching; (c) adding or fostering pathogenic organisms; (d) adding radioactive substances</td>
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<tr>
<td>5. Time</td>
<td>(a) Rejuvenating the soil through additions of fresh parent material or through exposure of local parent material by soil erosion (b) reclaiming land from under water</td>
<td>(a) Degrading the soil by accelerated removal of nutrients from soil and vegetative cover; (b) burying soil under solid fill or water</td>
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* The terms “beneficial” and “detrimental” are clearly subjective, but serve to stimulate discussion

Tab. 1: **Suggested effects of human influence on the five factors of soil formation** *(from BIDWELL & HOLE 1965).*
<table>
<thead>
<tr>
<th>Period</th>
<th>Event</th>
<th>Soil type</th>
<th>Soil process</th>
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<tbody>
<tr>
<td>Modern</td>
<td>Burial by blown sand—Settlement and cemetery (Wolds footslope)</td>
<td>Calcareous brown sand</td>
<td>Recalcification (neutralization)</td>
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<tr>
<td>Saxon</td>
<td>—Burial by blown sand—Heath?</td>
<td>Podzols</td>
<td>Podzolization 3</td>
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<td>Roman</td>
<td>Agriculture “Aeolian erosion”—Heath?</td>
<td>Podzols</td>
<td>Podzolization 2</td>
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<tr>
<td>Late Bronze Age</td>
<td>Agriculture</td>
<td>Humo-ferric podzols</td>
<td>Podzolization 1</td>
</tr>
<tr>
<td>— Early Iron Age</td>
<td>“Aeolian erosion”—Heath?</td>
<td>Argillic brown earth</td>
<td>Acidification</td>
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<tr>
<td></td>
<td>Agriculture</td>
<td></td>
<td>Decalcification</td>
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<td></td>
<td>Clearance?</td>
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<tr>
<td></td>
<td>Woodland regeneration?</td>
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<tr>
<td></td>
<td>—Burial by blown sand—“Aeolian erosion”</td>
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<tr>
<td>Early Bronze Age</td>
<td>Barrow construction</td>
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<td></td>
<td>—Burial by blown sand—“Aeolian erosion”</td>
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<tr>
<td>Late Neolithic</td>
<td>Area already cleared?</td>
<td>Calcareous brown sand</td>
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Tab. 2: Soil and environmental history at an archegological site in Yorkshire, based on the pedological evidence (from MACPHAIL 1986).

LACK 1986, 39). Calcretes are also common pedologic features in the sediments at Olduval, and studies of their carbon and oxygen isotopes provide valuable paleoclimatic data (HAY & REEDER 1978, CERLING & HAY 1986).

3 Soils as indicators of landuse

Human beings have a significant influence on soils (tab.1). BUTZER (1982, 123–156) and DAVIDSON (1982) present very useful summaries of the history and nature of such influence. In regions with a long history of human modification of the environment, considerable attention has been devoted to the study of soils as evidence of this. Of particular concern are the effects of forest clearance and cultivation.

Soil chemistry has been used throughout the western hemisphere to detect evidence of prehistoric landuse and modification of the soil (e.g., BERLIN et al. 1977, EIDT 1984). There is little information concerning such use of soils in North America, but there are several examples from Central and South America. OLSON (1983) evaluated the agricultural potential of Preclassic Maya soils in the Zapotitan Valley of El Salvador. These soils are generally buried by thick volcanic deposits, but have excellent physical and chemical properties from an agricultural standpoint, better than the modern, less weathered soils.
In western Belize MUHS et al. (1985) examined soils in order to determine the location of cacao orchards during the Postclassic-Colonial Period Maya occupation. The physical and chemical data indicated that the floodplain was the most likely area for cacao growth. At the Nambillo site, Ecuador, LIPPI (1988) used a systematic coring strategy to recover data for establishing the site stratigraphy and identifying buried landforms, and to recover samples for phosphate analyses which were used to identify areas of human activity. These data were then used to design an excavation strategy for the site.

Probably the widest application of soil studies in reconstructing landuse and assessing human impact on the landscape is in Europe, especially in Great Britain. MACPHAIL (1986), focusing on Europe, presents an excellent summary of some of the methods, particularly micromorphology, that can be used in such pedological research, and reviews the processes and effects relating to artificial modification of the soil (tab.2) (see also DAVIDSON 1982). He has summarized these events as follows:

“...In Europe...man's effects have been shown to be more decisive locally on pedogenic trends than any climatic change during the Flandrian [Holocene]. By causing massive soil erosion, through woodland clearance and agriculture, he created large areas of shallow calcareous soils, thus reversing the natural trend of decalcification. By accelerating the leaching rates on acid substrates such clearance triggered podzolization. Deforestation leading to decreased evapotranspiration rates also resulted in progressive upland hydro-morphism and peat formation, at a much earlier time in some cases, than the onset of cooler and wetter conditions of the sub-Atlantic phase. Thus limestones could have their decalcified topsoils removed by erosion, and the processes of podzolization and upland hydro-morphism could be hastened by the destruction of natural vegetation.” (MACPHAIL 1986, 283–284).

MACPHAIL's discussion and examples of these processes illustrate the many clues that soils can yield concerning the effects of human beings on the landscape. In thinsections, for example, coarse-grained illuvial coatings (“dusty clay coatings”) often indicate deforestation, and poorly-sorted mineral coatings and infillings of charcoal and organic matter are evidence of agriculture. Additional examples of micromorphological studies of soils to detect evidence for cultivation and other human activities is provided by FISHER & MACPHAIL (1985) and MACPHAIL et al. (1987) working in Britain, and by COURTY & NORNBERG (1985) in Denmark.

The importance of people in altering the landscape and associated soils can be overemphasized, however. For example, clay translocation and formation of soils with argillic horizons (sols lessivés) in south and east England are considered by some to be the result of forest clearance and cultivation (LIMBREY 1975). FISHER (1982) addressed this problem and convincingly shows that such an interpretation is not substantiated and the
sols lessivés were probably the "modal" forêt soils of the area prior to cultivation.

In the Mediterranean region DAVIDSON (1978) evaluated the agricultural potential of soils associated with a Minoan occupation at and prior to the eruption of Santorini (ca. 1500 B.C.). Examination of volcanic deposits indicated that soils on the pre-eruption surface were at best weakly developed, with low organic matter and clay contents, thus having low water and nutrient storage and being easily erodable.

LISTSINA (1976) studied arid soils of the Near East for clues to ancient farming and irrigation. Relative to virgin soils, those that were cultivated and irrigated near oases had higher salt and humus contents and showed evidence of increased biological activity.

4 Discussion and conclusions

From the foregoing it can be seen that soils have been used for a variety of purposes in archeological research throughout the world, and their importance in such studies seems to be generally recognized by archeologists and paleopedologists. Soils studies are not and never will be a panacea, and in many archeological sites are of little use; however, soils are still an under-utilized or misapplied resource in archeology. Such research is all too often treated as an "ancillary study" and the results relegated to undiscussed appendices (e.g. ALBANESE 1986). The stratigraphic and environmental significance of soils seems to be both underused and overemphasized in gearcheology. Soils are outstanding stratigraphic features, but they are also much more. They represent a period of significant landscape stability and as such are useful in reconstructing the landscape evolution of a region. This in turn can have regional environmental significance. Soils form over fairly long periods of time and because of this they are also useful as age indicators.

There are obvious relationships between soils and the environment (BUOL et al. 1980, JENNY 1980), but there are also considerable difficulties in using soils as paleoenvironmental indicators. As VALENTINE & DALRYMPLE (1976, 218) note "Although soil science is under great pressure to furnish environmental evidence, it is debatable whether we understand the interaction of the soil-forming processes with the site and environmental factors well enough yet to make confident extrapolations". BIRKELAND (1984) discusses documented and potential methods of using soils and pedological features for environmental reconstruction, but also notes the many pitfalls involved. He restates PAWLUK's (1978) well-taken admonition concerning pedological equifinality; that soils similar in appearance may have different genetic histories and these histories may not include environmental change.

An example of the problems that can be encountered when using soils for environmental reconstructions is found in the concept of "soil-forming intervals", which has been applied by many geoarcheological workers. Soil-forming intervals are discrete climatic episodes conducive to rapid soil formation hypothesized to have existed at various times in the Quaternary, largely in the central and western United States (MORRISON 1967, 1978). Clearly, certain environments are more conducive to soil formation than others. For example, soils in loess in the Upper Midwest of North America and in Central
Europe formed only during interglacial and interstadial periods when the climate was relatively warm and humid, and eolian deposition was very slow (PYE 1987). The occurrence of soil-forming intervals in regions not in proximity to ice sheets is less clear, however, and the concept is strongly challenged by some (BIREKLAND & SHROBA 1974, BOARDMAN 1985). For example, the presence of a buried soil or a well-developed soil may be related to non-climatic factors affecting landscape stability, and the timing and rates of sedimentation.

The best geoaarcheological example of this problem is the “Altithermal soil”, reported from many Holocene sites and characterized by a Bk horizon (e.g., LEOPOLD & MILLER 1954, MALDE & SCHICK 1964, HAYNES 1968, ALBANESE 1986). The carbonate accumulation is considered indicative of pedogenesis under warmer and probably drier conditions of the mid-Holocene “thermal maximum” or Altithermal (the Atlantic of the Blytt-Sernander scheme). The problem is that for most soils considered “Altithermal soils” there is little data regarding the age of the parent material or the duration of pedogenesis, i.e., there is no evidence that soil formation occurred in the middle Holocene. However, the assumption is made that because the soil has characteristics typical of drier climates it must have formed during the Altithermal. In at least some areas it is clear that profiles like the “Altithermal soils” formed in the late Holocene, and that it was the parent materials of the soils that were the result of the Altithermal climate. On the Southern High Plains of Texas and New Mexico, eolian sediments accumulated in dry valleys and as dune fields in the mid-Holocene, the result of Altithermal drought (HOLLDIAY 1989b). In the areas of eolian sedimentation, landscape stability and, therefore, conditions suitable for pedogenesis, did not obtain until the late Holocene.

The complex nature of pedogenesis is becoming more apparent, in and out of archeological contexts. Problems such as equifinality and the paleoclimatic significane of soils are being dealt with using increasingly sophisticated approaches and techniques such as micromorphology and the use of soils as dating tools, discussed above. There are other areas of research in pedology, paloopedology and the other geosciences that are generating results with promising geoaarcheological applications. The relationships between soils, the landscape, and landscape evolution, and the interpretation of landscape evolution from soils are reviewed in several volumes on soil geomorphology (GERRARD 1981, BIRKELAND 1984, RICHARDS et al. 1985). The identification of buried soils is often a problem (FENWICK 1985), but many mineralogical and chemical techniques are being developed to aid in their recognition (DORMAAR & LUTWICK 1983, JENKINS 1985). The isotopic composition of pedogenic carbonate is being used as an indicator of regional temperatures and of vegetation types (C3 vs. C4) and density during soil formation (CERRING & HAY 1986, AMUNDSON et al. 1989, QUADE et al. 1989). The paleoclimatic and age significance of soil carbonate is also being tested and evaluated by modelling experiments (MCFADDEN & TINSLEY 1985, MAYER et al. 1988). The magnetic properties of soils, especially magnetic susceptibility, are also proving useful in comparisons of
pedogenic development, in reconstructing pedogenic environments, and in detecting natural and artificial disturbances of soils, such as erosion and burning (DEARING et al. 1985, ALLEN & MACPHAIL 1987, MAHER 1986).

The study of soils in archeological contexts or for archeological applications appears to be a widening field, especially as specific methods and applications such as those described in this paper are being developed. One hopes that this practice will continue to grow and become an integral part of geoarcheological research. Not only will such work provide more information for archeological interpretations, but also provide considerably more data on soils themselves.

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