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Use and Analysis of Soils by Archaeologists and Geoscientists

A North American Perspective

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1. Introduction

Archaeologists generally recognize that there is a relationship between cultural deposits and associated soils and landforms. However, their understanding of what a soil is, as well as what soils can reveal about site formation processes, landscape development, and environments of the past varies greatly. Although archaeologists should not be expected to have a complete grasp of pedology, they should be capable of recognizing and interpreting soils in an archaeological context in order to fully comprehend the record of the human past.

A large body of literature addresses the use of soils in archaeological research. Some of it provides general discussions of applications of pedology to archaeology (e.g., Butzer, 1971, 1982; Cornwall,1958; Evans, 1978; Foss et al., 1995; Holliday, 1990; Limbrey, 1975; Lotspeich, 1961; Rapp and Hill, 1998; Shackley, 1975; Tamplin, 1969; Waters, 1992:40–60). In geoarchaeological

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studies, the focus on soils is often their use as stratigraphic markers (e.g., Artz, 1985; Bettis and Thompson, 1981, 1982; Cremeens and Hart, 1995; Ferring, 1986, 1990, 1992; Gvirtzman et al., 1999; Hajic, 1990; Holliday, 1985a,1985b,1905c,1989; Holliday and Meltzer, 1996; Hoyer, 1980; Mandel, 1992, 1995; Nordt, 1992, 1995; Reider, 1980, 1982, 1990; Styles, 1985; Thoms and Mandel, 1992; Wiant et al., 1983). There is also substantial literature that considers soil chemistry, especially phosphorus, as an indicator of the presence and/or intensity of human occupation and for interpreting use areas within sites (e.g., Ahler, 1973; Brinkmann, 1996; Eidt, 1977, 1985; Gordon, 1978; Groenman-van Waateringe and Robinson, 1988; Jacob, 1995; Kolb et al., 1990; Sandor, 1992; Schuldenrein, 1995; Sjoberg, 1976; White, 1978; Woods, 1984). Soil micromorphology is used in an increasing number of investigations as a tool for interpreting the geoarchaeological context of deposits (e.g., Courty, 1992; Courty et al., 1989, 1991; Fisher and Macphail, 1985; Goldberg, 1983, 1987, 1992; Holliday, 1985c; Holliday et al., 1993; Macphail, 1986, 1992; Macphail and Goldberg, 1995; Macphail et al., 1990, 1994; Mikkelsen and Kangohr, 1996). Other studies have used broader scale archaeological applications of pedology to landscape and climatic reconstruction (e.g., Bettis and Hajic, 1995; Haynes and Grey, 1965; Holliday, 1997; Johnson and Logan, 1990; Mandel, 1992, 1995; Monger, 1995; Paulissen and Vermeersch, 1987; Ranov and Davis, 1979; Reeves and Dormaar, 1972; Reider, 1980, 1982, 1990; Thompson and Bettis, 1980) and have demonstrated the utility of soils as dating tools in archaeological research (e.g., Anderton, 1999; Bischoff et al., 1981; Frink, 1995; Holliday, 1988).

Faced with this vast amount of useful, but often highly technical information from disciplines not often considered in their academic training, archaeologists are frequently left with the following questions: What does one need to know about soils, in a practical sense, when conducting field investigations? What types of soil data are critical to the resolution of archaeological problems, and how does one go about collecting these data? Our chapter addresses these questions. Specifically, we (1) explain why it is important for archaeologists to understand the difference between soil and sediment, (2) describe how to distinguish soil from sediment, and (3) discuss the type of soil information needed at different stages of an archaeological investigation, that is, surveys versus site evaluations versus excavations. Although approaches for collecting soil data are considered, detailed discussions of soil-forming factors and processes, physical and chemical properties of soils, and soil profile nomenclature are not presented here; the reader is directed to other sources for this information (see Birkeland, 1999; Buol et al., 1997; Catt 1986; Soil Survey Division Staff, 1993; Soil Survey Staff, 1996).

2. Distinguishing Soil from Sediment

The Soil Survey Staff (1996: 1) provided the following definition of soil: "soil" is a term used for "the natural bodies, made up of mineral and organic materials, that cover much of the earth's surface, contain living matter and can support vegetation out of doors, and have in places been changed by human activity."

This all-encompassing definition provides for a soil continuum across the present land surface but is inadequate for the four-dimensional (horizontal, vertical, time, environment) landscape analysis necessary in archaeological investigations. Archaeologists and soil geomorphologists alike must distinguish between characteristics of deposits that are a product of sedimentary processes and those that are indicative of secondary alterations related to weathering at a land surface (soil formation). This distinction is important because in most cases a soil signifies a break in deposition; hence it is an indicator of a relatively stable land surface and a zone that represents more time to record human activities than adjacent nonsoil.

Many factors interplay to produce the characteristics of soils, but one characteristic all soils have in common is a vertical sequence of genetically related horizons produced by soil-forming processes acting on geologic materials over time (Fig. 1). The concept that soil horizons require some amount of time to form is probably one of the most significant aspects of pedology in archaeology (Holliday, 1990:530). Another important consideration is that soil development requires not only time but also a relatively stable landscape, one that is neither rapidly aggrading or eroding (Catt, 1986:166–167). Exceptions are bogs and marshes, where organic soils (Histosols) form as a result of accumulation of organic matter. Also, soils on floodplains and on toeslopes may receive influxes of parent material while pedogenesis is underway; that is, soil formation and deposition proceed concurrently (Birkeland, 1999). Disregarding these exceptions, the presence of a soil indicates that the landscape has been relatively stable for a period of time. In general, landscapes that have been stable for long periods have soils that are better developed than those that have been stable for short periods, all other soil-forming factors being equal.

A buried soil in a stratigraphic sequence indicates a hiatus between depositional events. Holliday (1992) stressed that in such a sequence "the sediment, which is the parent material for the soil, may have accumulated rapidly or slowly, but a significant period of nondeposition had to occur for the soil to form (p. 103)." Although large volumes of sediment may be deposited instantaneously, as with a debris flow, soil formation usually requires at least a century or several centuries and commonly millennia (Birkeland, 1999; Holliday, 1992).

In archaeological investigations, consideration of landscape stability, as indicated by soil development, is important in locating cultural deposits, interpreting artifact associations and contexts, defining site stratigraphy, reconstructing the depositional and landscape history, and establishing cultural chronologies. The first step is identifying which parts of the sedimentary deposits present in the site or study area have been modified by soil formation. Although this can be a fairly straightforward task, it often becomes complicated when pedogenically unaltered deposits have properties that mimic some properties of soils.

The first step in the recognition of a soil is the identification of soil horizons and the development of the ability to differentiate between soil horizons and sedimentary deposits with soil-like properties. Soil horizons often parallel a land surface, and they have distinctive properties that result from the complex interactions among a variety of physical, chemical, and biological processes acting on surficial materials over time. The nature and magnitude of influence of these

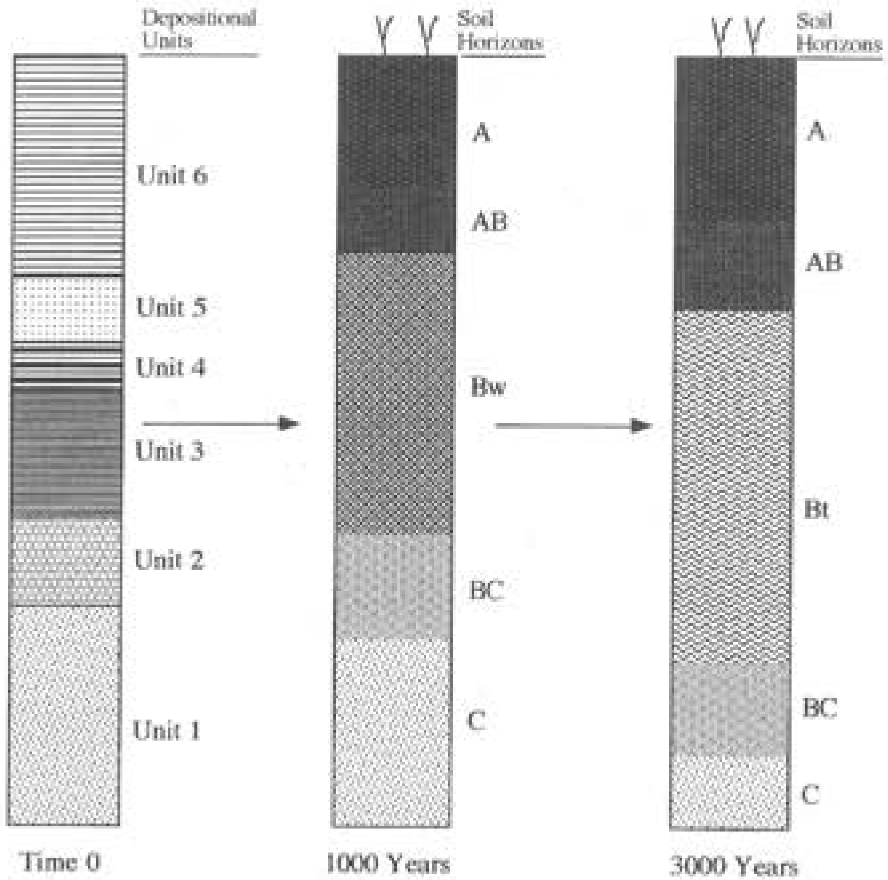

Figure 7.1. The transformation of pedogenically unmodified sediment (parent material) into a soil. At time 0, the sediment is contained in six distinct stratigraphic units that are separated by abrupt boundaries. After 1,000 years of landscape stability, a hypothetical soil with an A-AB-Bw-BC profile has developed in the units, obliterating primary sedimentary features, such as bedding. After 3000 years of landscape stability, the hypothetical soil is thicker and much better developed (A-AB-Bt-BC profile). Note that the soil horizons bear little resemblance to the original stratigraphy.

processes, and the resulting properties of soils, is in large part controlled by various environmental factors. Both soils and unlithified geologic materials that are not soils can be described according to the following properties: color, texture, consistence, soil structure (or lack thereof), cutans (coatings), nodules or concretions, voids, reaction to hydrochloric acid, boundary characteristics, and horizon continuity. Specifics on the nomenclature for describing soil horizons and surficial materials are provided by Birkeland (1999), Birkeland et al. (1991), Buol et al. (1997), Hallberg et al. (1980), and the Soil Survey Staff (1996).

Distinguishing soil from sediments on the basis of the presence or absence of horizons is not always a simple procedure. For example, organic- or clay-rich

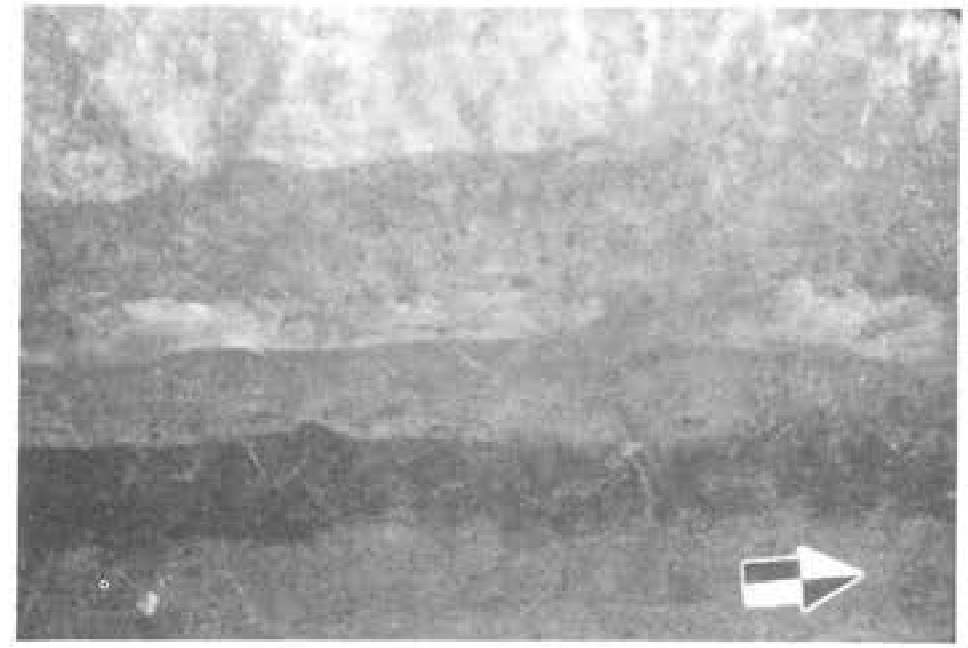

Figure 7.2. Stratified alluvium exposed in an archaeological test pit at site 13HA385 in north-central Iowa. A dark, organic-rich flood drape near the bottom of the pit could be confused with a buried A horizon. However, note the abrupt lower boundary of the flood drape. The photo scale is 20 cm long.

alluvium that has not been modified by pedogenesis sometimes exhibits properties that mimic those of A and B horizons of soils, respectively (Fig 7.2). Several criteria may be used to discriminate a soil horizon from a depositional unit in an alluvial setting. The lower boundary of an A or B horizon, for example, is usually clear, gradual, or diffuse, rather than abrupt or wavy (Fig 7.3). Pedogenically unaltered clay- and organic-rich depositional layers often have abrupt and wavy boundaries or graded bedding produced by sedimentary processes. As the deposits are affected by bioturbation and other soil-forming processes, the abrupt boundaries that separate individual beds are obliterated. Micromorphological studies may help distinguish soil horizons from sedimentary zones in these situations by identification of fabrics indicative of mixing, soil-forming processes, or sedimentary processes (Courty, 1992; Courty et al., 1989).

Soil structure, which is the aggregation of primary soil particles into distinctively shaped compound particles (peds), can be used to distinguish organic-rich sedimentary deposits from A horizons of soils. Flood drapes, which tend to be clayey and enriched with organic matter, often contain clay minerals that shrink and swell with drying and wetting. The shrinking and swelling of the these minerals gives the dark alluvium an angular blocky "structure" that may be misinterpreted as having been formed by processes associated with a relatively stable land surface during a hiatus in sedimentation. An A horizon, however,

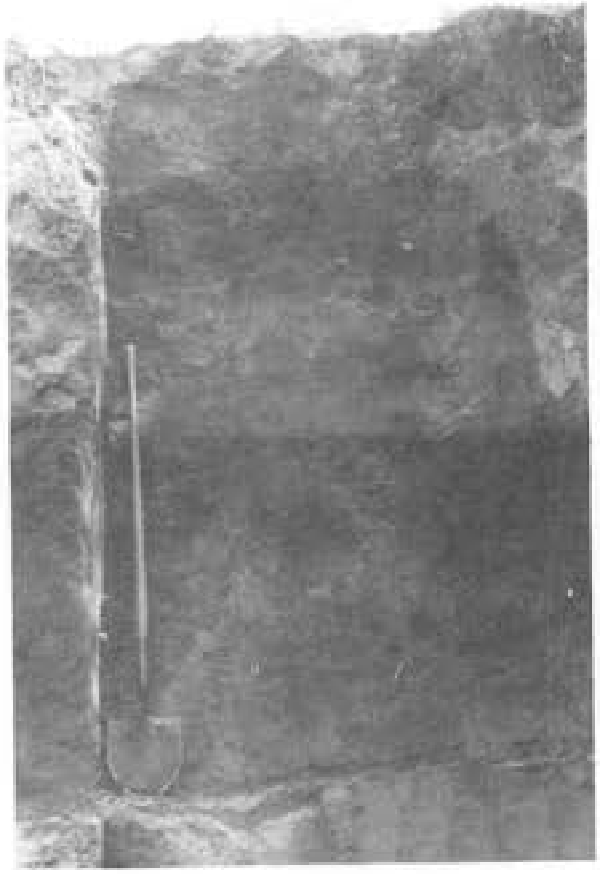

Figure 7.3. Buried soils developed in alluvium at the Alum Creek site in central Kansas (Mandel, 1992). There is a thin buried A horizon immediately above the handle of the shovel, and the shovel is leaning against a dark, overthickened A horizon. Note the gradual lower boundaries of the buried A horizons, and compare them with the abrupt lower boundary of the organic-rich flood drape in Fig. 7.1.

typically has granular structure produced by the activity of worms and other soil organisms in this biologically active zone of the soil. In buried soils, the granular structure may be transformed to blocky types of structure during compaction, but evidence for the former A horizon may include greater porosity or granular aggregates that can only be detected in soil thin sections (Courty, 1992; Courty et al., 1989). Patterns of rooting and burrowing also provide useful information for identifying former land surfaces and for distinguishing soils and unaltered sediments. Unaltered sediments are usually capable of supporting plant life and often become burrowed, but surfaces stable enough for soils to form are subject to more intensive rooting and potentially more burrowing activity simply because

they represent more time per volume than unaltered deposits. The upper horizon of a soil, therefore, should be more heavily rooted, especially with fine roots, and should contain more evidence for bioturbation than unaltered deposits. Because of the dark color of many soil surface horizons, and the rate of bioturbation and the small scale of many bioturbators, such as worms and ants, much of the conclusive rooting- and burrowing-pattern evidence for distinguishing soil horizons from unaltered deposits is at the microscopic scale (Courty, 1992).

In some areas of North America, especially arid and semiarid regions, deposits that have been affected by nonpedogenic accumulations of calcium carbonate can be easily confused with calcic soils. For example, laterally flowing, $CaCO_3$-rich groundwater often forms calcretes that are misidentified as soils with petrocalcic horizons (Machette, 1985). The development of a groundwater calcrete is a nonpedogenic process that requires calcium-charged groundwater to either discharge onto a stream bottom or reach a near-surface position where calcium is concentrated by evaporation. Supersaturation of calcium causes precipitation of $CaCO_3$ and subsequent cementation of relatively porous sands and gravels (Machette, 1985). Further complicating matters, surface runoff may add or redistribute the $CaCO_3$ and produce laminar zones that resemble laminar petrocalcic horizons (Bachman and Machette, 1977). Nevertheless, with careful field observations and micromorphological analyses, it is possible distinguish groundwater calcretes from calcic soils. For example, groundwater calcretes are often strongly indurated to depths of 10 m or more (Machette, 1985). Petrocalcic horizons, however, are rarely more than several meters thick. When viewed in thin section, groundwater calcretes typically consist of simple cement fills enclosing clasts with grain-to-grain contact, whereas the cement of petrocalcic horizons is micritic and replaces or surrounds scattered detrital grains that appear to float in a matrix of carbonate (Arakel, 1986; Jacobsen et al., 1988; Machette, 1985). Also, groundwater calcretes generally lack the horizonation and morphological structures common in calcic soils (Allen, 1986; Bachman and Machette, 1977; Machette, 1985; Wright, 1982).

In an archaeological investigation, it is important to distinguish between a ground-water calcrete and a petrocalcic horizon because of the temporal, soil-stratigraphic, and environmental implications. Ground-water calcretes form in tens to hundreds of years, they are not products of landscape stability, and they develop in a wide range of environments (humid to arid). Petrocalcic horizons, however, require thousands of years of carbonate accumulation in relatively stable arid or semiarid soil-forming environment (Birkeland, 1999; Gile and Hawley, 1966; Gile et al., 1979).

In some situations, sandy C horizons may be confused with albic (E) horizons of soils. This usually occurs where a light-colored sandy C horizon is beneath an A horizon and above a truncated Bt horizon. Such confusion may seriously compromise the interpretation of the soil-stratigarphy, paleoenvironment, and age of an archaeological site. An E horizon is a product of intensive leaching (eluviation) that typically spans thousands of years, whereas a C horizon consists of slightly weathered parent material. The best approach to distinguishing a C horizon from an E horizon is to examine the morphology of the soil. For example, all E horizons have soil structure, which involves a bonding together of individual soil particles. In most E horizons, the particles are arranged about a horizontal plane, forming platy structure (Birkeland, 1999). In contrast, sandy C horizons are single grain or massive; hence, they are structureless. If the material is single grain, the individual particles are easily distinguishable and do not adhere to each other. When the material is massive, individual particles adhere closely to each other, but the mass lacks planes of weakness (Buol et al., 1997). Also, the boundary between an E and a Bt horizon is usually gradual and wavy or irregular, and tongues of the E horizon often extend down into a Bt horizon. In contrast, where a C horizon overlies a truncated Bt horizon, the boundary is abrupt and smooth or wavy and lacks tongues.

Soils, unlike most individual beds of sediment, are laterally extensive across the landscape. They extend across various landforms and underlying geologic deposits and exhibit predictable variations in their properties related to changes in drainage, vegetation, and relative age of the geomorphic surface on which they occur. Hence, surface and buried soils can be mapped in three dimensions over varying topography. In contrast, individual beds of sediment tend to be restricted to a certain depositional environment and will pinch out away from that area (Fig 7.4).

Although identification and study of soils begin in the field with careful observations, it is sometimes necessary to support these observations with laboratory analysis in order to clearly differentiate soil from pedogenically unaltered sediment. One of the most powerful laboratory methods for distinguishing soil from nonsoil is micromorphological analysis (see Fisher and MacPhail, 1985). This procedure, which requires the use of thin sections and petrographic equipment, greatly enhances the ability of the soil scientist to identify micropedological features, such as soil plasma, voids, skeletal grains, and cutans (Brewer, 1976; Bullock et al., 1985; Courty et al., 1989). However, as Wilding and Flach (1985) pointed out, soil micromorphology is a powerful tool to extend macromorphology and should not be used alone to distinguish soil from sediment. Because many soil properties form by the vertical movement and accumulation of some material, such as clay, iron, and calcium carbonate, a wide variety of laboratory methods, such as grain-size and chemical analyses, can be helpful in differentiating soil from pedogenically unaltered sediment (Buol et al., 1997; Hesse, 1971; Soil Survey Staff, 1996).

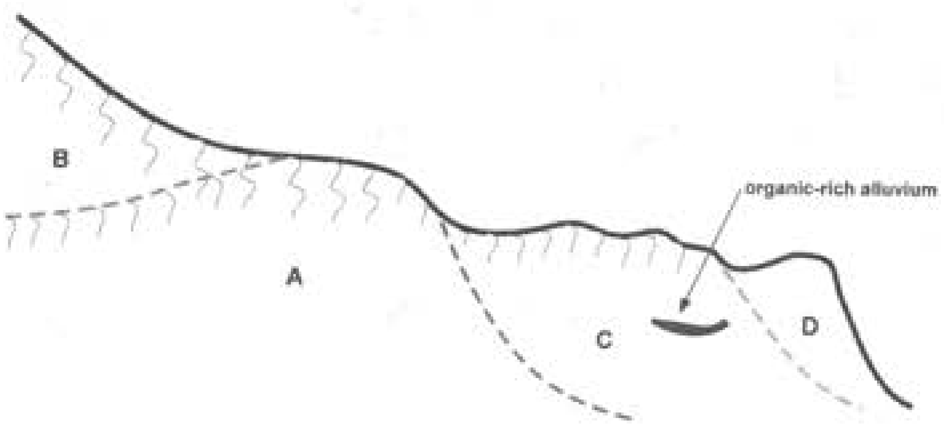

Figure 7.4. Soils form a continuum across the landscape and cross landform and parent material boundaries. The diagram shows a surface soil developed across several landforms of different ages. Organic-rich alluvium sometimes has properties similar to soils, but does not extend across the landscape to the degree that soils do. In this example, the organic-rich alluvium is restricted to one depositional unit (C) and does not cross-landform and parent material boundaries.

3. Soils and Archaeological Surveys

A major aspect of archaeological research involves surveying the landscape for evidence of the human past. In the United States, most archaeological surveys are related to government-mandated cultural resource management (CRM) projects (Green and Doershuk, 1998). Archaeological surveys are also common outside the United States, though they tend to be associated with projects sponsored by research institutions and foundations (e.g., Hassan, 1978; Simmons and Mandel, 1986; Wendorf and Schild, 1980). Regardless of the driving forces, archaeological surveys often encompass many different elements of the modern landscape. Because these landscape elements may be underlain by deposits with varying ages and depositional histories, archaeological surveys should be supported by geomorphological investigations in order to provide archaeologists with important information regarding the effectiveness of various sampling strategies in the survey areas.

With archaeological surveys, the problem of locating sites of a particular cultural period is one of determining where in the landscape sediments of that period are preserved (Artz, 1985). In other words, knowledge of the distribution of the various-age deposits that comprise present landscapes is essential in order to evaluate those landscapes for evidence of past human occupation (Bettis, 1992:132). In most areas, soil variability across the landscape is an important indicator for estimating the age of landforms and sediment assemblages that underlie them. Many studies have demonstrated that the degree of soil development provides important clues to the relative ages of geomorphic surfaces and underlying deposits (e.g., Bettis, 1992; Birkeland, 1999; Birkeland and Burke, 1988; Dethier, 1988; Gile et al., 1981; Harden, 1982; Holliday, 1992; Karlstrom, 1988; McFadden and Weldon, 1987; Yaalon, 1971). Because surface soils can provide relative time control and are mappable, they may be used to devise "quick and dirty" strategies for assessing the cultural resource potential of a survey area. This approach was employed in several major archaeological surveys, including ones in Texas (Lake Creek valley: Mandel, 1987), Oklahoma (Copan Lake area: Reid and Artz, 1984), and Iowa (central Des Moines River valley: Benn and Bettis, 1985; Bettis and Benn, 1984). The survey of the central Des Moines River valley is considered in the following discussion.

A detailed soil-geomorphic investigation was undertaken prior to an intensive archaeological survey and testing program in the Des Moines Valley (Bettis and Benn, 1984). This study demonstrated that certain properties of surface soils developed in Holocene alluvium of midwestern streams are age diagnostic (Bettis, 1992). For example, surface soils formed in early and middle Holocene alluvium are Mollisols with argillic (Bt) horizons or Alfisols. These soils exhibit moderate grade structure, brown or dark brown Bt horizons, few to common argillans, and are well horizonated. In contrast, surface soils developed in late Holocene alluvium are Mollisols or Inceptisols with cambic (Bw) horizons, or Mollisols that lack B horizons. These soils tend to be dark colored throughout, exhibit weak to moderate grade structure, and have weak horizonation. Finally, surface soils developed in Historic deposits are Entisols with thin, weakly expressed A–C profiles. This soil information was combined with other geomorphic and stratigraphic data to construct maps that show the distribution of landform sediment assemblages dating to different periods of the Holocene. These maps provided valuable information used during subsequent archaeological surveys to devise sampling strategies for locating the valley's archaeological deposits. This information also provided archaeologists with estimates of past landscapes removed by river processes. These estimates proved invaluable for interpreting the pattern of known sites in the survey area in terms of past land use patterns (Benn and Bettis, 1985).

Although soils data should be collected by the geoscientist(s) involved in an archaeological survey, soil surveys published by the U.S. Department of Agriculture provide some information useful for planning the archaeological investigation (Almy, 1978; Saucier, 1966). These surveys are available at county and state offices of the Natural Resources Conservation Survey (formerly the Soil Conservation Service). Each survey covers one or two counties and consists of a brief text accompanied by a series of photomosaic or photomap base sheets on which the soil series are outlined in red or in black. The photomaps vary in scale from 1:7,920 to 1:31,680, but most are at a scale of 1:20,000. Individual sheets cover an area of approximately 12 square miles and measure about 9.5 by 12.5 inches. The Natural Resources Conservation Survey (NRCS) is presently digitizing these maps so they can be electronically accessed. Because the relative age and geomorphic stability of surfaces are reflected in some of the properties of soils, the NRCS soil maps may indicate, within broad limits, the relative ages of sediments and sites to be expected in a given area (Artz, 1985). Also, soil drainage may be inferred from these maps, which in turn can be used to isolate poorly drained landscapes with low potential for archaeological sites from well-drained areas with high archaeological potential. However, the soil surveys are generalized and should only be used to establish initial impressions of soil–geomorphic relationships in the study area. Detailed field investigations are required to confirm and elaborate on those impressions and to refine them to the scale (both spatial and temporal) needed by most archaeologists (Artz, 1985).

As noted earlier, buried soils represent previous land surfaces that were exposed for sufficient periods of time to develop recognizable soil profile characteristics. Hence, they represent former stable land surfaces. If one assumes that the probability of cultural utilization of a particular landscape position is

equal for each year, it follows that the surface that remains exposed for the longest time would represent those with the highest probability of containing cultural remains (Hoyer, 1980:61). Because buried soils represent former stable surfaces, evidence for human occupation would more likely be associated with them. This reasoning also implies that a soil that had the most time to develop before it was buried would have the highest potential for containing cultural deposits at any given location. Thus, buried soils are also useful indicators for locating archaeological deposits and for assessing an important aspect of the geologic potential for buried cultural deposits.

Knowledge of the temporal and spatial pattern of buried soils in a landscape provides archaeologists with a powerful tool for identifying areas with high potential for buried cultural deposits and for assessing prehistoric cultural patterns. Although there are a number of good examples of how this knowledge can be applied in an archaeological survey (e.g., Bettis and Benn, 1984; Bettis and Littke, 1987; Mandel, 1992, 1994, 1996, 1997, 1999; Mandel et al., 1991; May, 1986; Thompson and Bettis, 1980; Ferring, 1992), only one example is presented here: the Phase II geoarchaeological survey of the Pawnee River Watershed in southwestern Kansas (Mandel, 1992).

The Pawnee River Survey was preceded by an intensive, basinwide study of Holocene alluvial deposits and associated buried soils (Mandel, 1992). Two distinct buried soils, the Hackberry Creek Paleosol and the Buckner Creek Paleosol, were identified beneath the first terrace (T–1) in small (<fourth-order) drainage elements (Fig 7.5) (Mandel, 1992). The T–1 surface stands about 3 m above the surface of the modern floodplain (T–0). A suite of radiocarbon ages suggested that the Hackberry Creek Paleosol formed from about 2,800 B.P. to ca. 2,000 B.P., and that the Buckner Creek Paleosol developed from ca. 1,700 to 1,000 B.P. These two paleosols are superposed and have thick, moderately expressed Ak–Bk profiles. Other buried soils were identified in the late Holocene alluvium that composes the T–1 fill, but they all have thin, weakly expressed A–C profiles that, individually, reflect only tens of years of pedogenesis (Mandel, 1992). Stratified Late Archaic and Plains Woodland cultural deposits were found in the Hackberry Creek and Buckner Creek paleosols, respectively, whereas buried soils with A–C profiles were consistently sterile of archaeological materials (Mandel, 1992). This finding underscores the axiom that the longer the period over which a soil has developed, the higher its potential for containing cultural deposits at any given location. The Hackberry Creek and Buckner Creek paleosols are important stratigraphic markers and were targeted for exploration during the archaeological survey that followed the geomorphological investigation of the Pawnee River basin.

Archaeologists doing surveys have become increasingly aware of the fact that buried soils often harbor much of the archaeological record in areas that were affected by episodic sedimentation throughout the Holocene. However, buried soils often occur at considerable depths; hence, they cannot be detected, much less assessed for cultural resources, using most conventional discovery methods. Faced with this dilemma, archaeologists have turned to sampling and discovery methods that have usually not been employed in past surveys. For example, engine-driven coring devices, such as hydraulic soil probes, can be used to

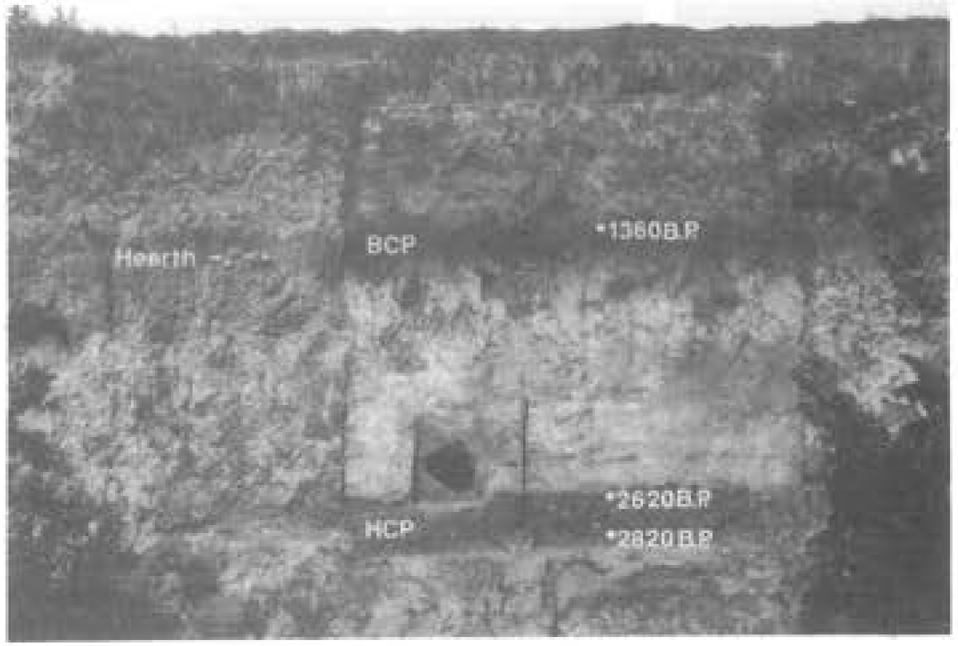

Figure 7.5. The Buckner Creek site (14HO306) on the east bank of Buckner Creek in southwestern Kansas (from Mandel, 1992, Fig. 2-13). The site was discovered in 1986 during a systematic geoarchaeological survey of the Pawnee River basin (Mandel, 1988). Plains Woodland materials, including a hearth, are associated with the Buckner Creek Paleosol (BCP). The Hackberry Creek Paleosol (HCP) contains stratified Late Archaic deposits at depths of 3.9 to 5.3 m below land surface. The shovel is approximately 1.5 m long. Courtesy Smithsonian Institution Press.

recover intact sediment cores to great depths. This type of mechanical coring is a very efficient method for determining the presence or absence of buried soils in a depositional environment—an important step in determining the geologic potential for buried cultural materials. When buried soils are encountered, they can be easily described from the cores and, if sufficient organic carbon is present, can be dated by radiocarbon analysis. Recent studies have also suggested that fine screening of soil recovered from the cores, and examination of the residue for microdebitage, may aid the discovery of deeply buried archaeological deposits (Stafford, 1995). Once the temporal and spatial patterns of buried soils are known for an area, strategies for subsurface exploration, such as trenching, auguring, and/or inspection of cut banks, can be developed. Even preliminary soil–stratigraphic frameworks that lack absolute time control greatly improve the efficiency and scientific outcome of archaeological surveys (Ferring, 1992).

Since the early 1980s, it has become obvious that surface soils developed on "stable" landscape positions underlain by "old" deposits sometimes contain buried archaeological materials (Artz, 1993, 1995b; Bettis and Hajic, 1995; Van Nest, 1993). This realization has come about primarily because of the implementation of shovel testing during archaeological surveys. However, the theoretical

foundations for understanding the burial of cultural deposits in stable upland settings are rooted in pedology and have recently been articulated by Johnson (1990) and by Johnson and Watson-Stegner (1990). Upbuilding of the soil through biomechanical processes may result in the burial of artifacts and cultural features. Some of the primary biological agents of soil upbuilding are ants, termites, and earthworms, all of which can quickly bury surface-occurring materials beneath their mounds or castings (Balek, 1998; Darwin, 1881; Johnson, 1990; Johnson and Watson-Stegner, 1990; Rolfsen, 1980; Stein, 1983; Wood and Johnson, 1978; Van Nest, 1998). For example, in regions where earthworms are extremely active, items may be buried to depths as great as 45 cm below ground surface in about 5 years (Rolfsen, 1980). Hence, worm castings, combined with soil brought to the surface by burrowing animals and tree-throws, form a biomantle that may conceal artifacts on stable uplands (Johnson 1990; Schaetzel et al., 1986; Van Nest, 1993, 1998). The major obstacles preventing a better understanding of site formation processes in these landscape positions are a paucity of datable material, and mixed artifact assemblages because of natural and anthropogenic pedoturbation. A lack of creative approaches to upland archaeological survey is also a major hindrance (Bettis and Hajic, 1995). However, soils can provide information regarding the relative degree of biological activity or soil disturbance across an upland area and can thus provide clues to the potential for burial or site mixing.

4. Soils and Site Evaluations

The discovery of an archaeological site is sometimes followed by an investigation that focuses on the significance of the find. In the United States, site evaluation is a standard procedure with CRM archaeology because of the need to develop and provide information for thoughtful decision making on the disposition of cultural resources that are threatened and/or being considered for National Register eligibility (see Green and Doershuk, 1998). Not all site evaluations, however, are related to a CRM project. For example, foundations and institutions that fund archaeological excavations in the United States and elsewhere often recommend or demand evaluations to determine whether a site warrants the effort and expenditure of resources needed for an excavation.

In most cases, site evaluations must resolve the following questions: What is the depth, horizontal extent, and stratigraphic context of the archaeological materials at the site? Does the site have good vertical and horizontal integrity (i.e., are the archaeological materials *in situ*)? How old are the cultural deposits? Information gleaned from soils at a site may contribute significantly to answering these questions.

Although the boundaries of a site that consists of archaeological materials at or very near the land surface can be easily determined by traditional methods, such as surface collection and excavation of shallow test units, deeply buried cultural deposits can make this procedure difficult. However, if the buried materials are on former stable surfaces (associated with buried soils), soil stratigraphy, combined with deep testing, may be used to determine the spatial limits of cultural deposits.

A good example of a soil stratigraphic approach to site evaluation is a recent investigation that focused on deeply buried cultural deposits associated with an alluvial fan (McNeal Fan) in the Mississippi River valley near Muscatine, Iowa. The proposed construction of a highway across the McNeal Fan initiated an intensive evaluation to assess the significance of the cultural resources. Artz (1995a) determined that three major depositional units underlie the surface of the fan, and that the thickest body of sediment, Unit II, consists of multiple upward-fining sequences (Fig 7.6). Soils are developed at the top of each upward-fining sequence, and archaeological materials are on and within the buried soils. Given the need to determine the lateral extent of the cultural deposits, the McNeal Fan presented a formidable challenge because the cultural deposits are at depths ranging from 0.5 to 8.5 m. Nevertheless, Artz (1995a) was able to define the spatial limits of each buried cultural zone by using a deep auguring device and a backhoe to trace the artifact-bearing soils. In addition, he demonstrated that the fan's soil stratigraphy was very complex because some of the buried soils merge downslope to form welded soil complexes, and locally throughout the site, buried soils are truncated by channels or sheetwash erosion. His findings were critical to the development of excavation strategies that targeted some areas of the site for investigation while avoiding other areas.

Soil evidence is especially useful for determining how and to what extent cultural deposits have been affected by post occupational disturbance processes, such as tree throws, animal burrowing, frost heaving, and erosion. Many disturbance processes result in characteristic soil features that can be recognized with field observations. For example, soils that have been affected by tree throws will have inverted profiles; that is, B-horizon material overlies A-horizon material (Johnson and Watson-Stegner 1990; Schaetzel et al, 1986). Where soils have been

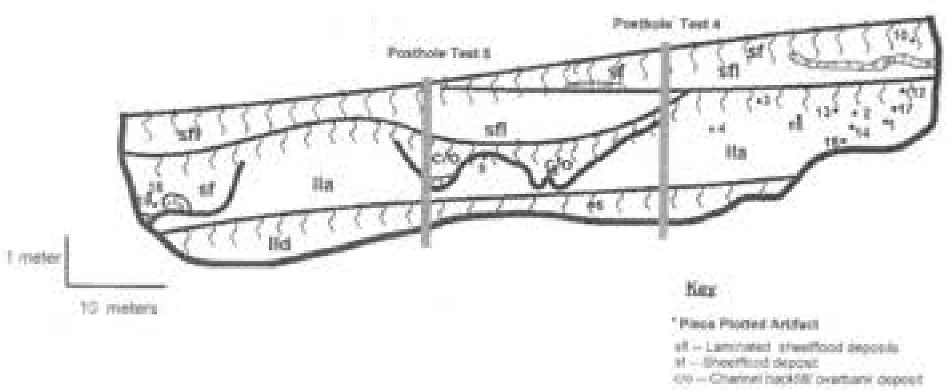

Figure 7.6. Profile of the east wall of Trench 2, Southwest Area, at the McNeal Fan (site 13MC15) in eastern Iowa (from Artz, 1995a, Fig. 19). Soils are developed at the top of each upward-fining sequence, and archaeological materials are within the buried soils. Courtesy Office of the State Archaeologist, University of Iowa.

disturbed by burrowing animals (faunalturbation), krotovina and other biogenic features are likely to be common in the mixing zone, and boundaries between soil horizons will tend to be diffuse (Buol et al., 1997). Cryoturbation, which is soil mixing by seasonal freezing and thawing of the ground, is often indicated by sand wedges, soil deformation, stone polygons and/or stripes, solifluction lobes, and by diagnostic micromorphological features (Van Vliet-Lanoe, 1985; Van Vliet-Lanoe et al., 1984; Wood and Johnson, 1978). Sheetwash erosion may be indicated by truncated soil horizons and rills. Isolated sand- or gravel-filled channels cut in the surface of a buried soil are good evidence of gully erosion. When the magnitude of soil disturbance processes is determined at a site, the potential impact of these processes on the vertical and/or horizontal integrity of the cultural deposits can be assessed (Schiffer, 1987; Wood and Johnson, 1978).

Simply recognizing buried soils in a stratigraphic sequence at an archaeological site has important implications in the evaluation of site formation and preservation processes. For example, it is likely that artifact densities will be greater on and within the buried soils compared to the zones of pedogenically unmodified sediment, but the impacts of pedoturbation on artifacts and on occupation zones are usually greater in the buried soils (Holliday, 1990). This does not imply that archaeological materials associated with buried soils will lack integrity. Some buried soils will harbor cultural deposits that are relatively undisturbed, whereas other buried soils in similar depositional environments will contain archaeological materials that have been greatly displaced by biological and geological processes. Ferring (1992) stressed that in order to determine which buried soils will have well-preserved cultural deposits, one must consider the nature of soil development in a depositional environment. He compared cumulative and noncumulative soils to make his point. Cumulative soils have parent material continuously added to their surfaces while pedogenesis is occurring (Birkeland, 1999), whereas noncumulative soils form during periods of nondeposition. Burial of cultural deposits in a cumulative soil protects artifacts and features from erosional disturbance and active, near-surface bioturbation. In contrast, archaeological materials that were left on the surface of a noncumulative soil were subject to more intense, adverse modifications before they were buried.

It is important to note that a cumulative soil profile is not a requisite for the preservation of cultural deposits. For example, at the Cherokee Sewer site in northwestern Iowa, most of the buried soils have thin, weakly developed profiles (A–C or A–Bw horizonation) that are products of brief episodes of pedogenesis on the rapidly aggrading surface of an alluvial fan (Hoyer, 1980). Archaic cultural horizons that represent short periods of human occupation on the fan are well preserved in poorly developed buried soils that are far below the modern surface soil. The primary context of the archaeological materials was maintained because the soils were not exposed to erosion or pedoturbation processes for long periods before they were buried. In addition, the soils were isolated from postdepositional modifications because of rapid, deep burial. Hence, the depositional environment of the fan (i.e., nearly continuous sedimentation interrupted by brief episodes of stability and pedogenesis) allowed excellent preservation of the material remains from short-term occupations. A similar relationship between the duration of pedogenesis and integrity of archaeological materials is reported for buried soils developed in alluvial fan deposits in the lower Illinois River valley (Wiant et al., 1983), the central Des Moines River valley (Bettis and Benn, 1984), and the upper Mississippi River valley (Artz, 1995a; Bettis et al., 1992). As Ferring (1992) pointed out, "to understand preserved soil-stratigraphic positioning of archaeological materials, it is necessary to document patterns of pedogenesis and sedimentation" (p. 19).

Determining the age of cultural deposits also is a very important aspect of a site evaluation. However, some sites that appear to be significant may lack time-diagnostic artifacts and radiocarbon-datable cultural material. Where this occurs, soils may be used to determine chronologic relationships of the archaeological materials. There are three approaches to using soils for dating archaeological sites: (1) determine the numerical age of organic carbon in soils; (2) correlate soils that are well dated with soils that lack temporal control; and (3) use data derived from a soil chronosequence to estimate the age of other soils in similar setting.

The most common method for determining the numerical age of soil is radiocarbon (^{14}C) dating of soil humates. A ^{14}C age determined on humates is the mean residence time for all organic carbon in the soil sample (Birkeland, 1999; Matthews, 1985). Although mean residence time does not provide the absolute age of a soil, it does give a minimum age for the period of soil development, and it provides a limiting age on material overlying a buried soil (Birkeland 1999:150; Geyh et al. 1975; Haas et al., 1986; Martin and Johnson, 1995; Matthews, 1985; Scharpenseel, 1971). When ^{14}C ages are determined on organic carbon from superposed buried soils, the relative age of cultural deposits bounded by the dated soils can be reasonably estimated (Mandel, 1992).

A relatively new method for determining the numerical age of soil is the Oxidizable Carbon Ratio (OCR) dating procedure (Frink, 1995). This procedure measures the specific rate of biodegradation of organic carbon, either as soil humic material or as charcoal. In general, as the total amount of organic carbon decreases through time due to biological recycling, the relative percentage of readily oxidizable carbon increases (Frink, 1992). This ratio is called the Oxidizable Carbon Ratio, or OCR. Although not fully tested, the OCR dating procedure provides a mean age of the total carbon in the sample (Frink, 1995).

The timing of pedogenesis has been firmly established for some late Quaternary soils through intensive ^{14}C dating of charcoal from cultural deposits (e.g, Artz, 1985; Ferring, 1986, 1990, 1992, 1995; Holliday, 1985a; Holliday et al., 1983, 1985; Mandel, 1992, 1994, 1995; Reid and Artz, 1984; Thoms and Mandel, 1992). By correlating soils, this temporal information can be used to date archaeological deposits at localities where absolute time control is absent. For example, in northeastern Oklahoma and in southeastern Kansas, a buried cumulative soil with a distinct overthickened A horizon is developed in late Holocene alluvium. This soil, often referred to as the Copan paleosol (Artz, 1985; Hall, 1977; Mandel, 1993a, b), developed between ca. 1,900 and 900 yrs B.P. Because the Copan paleosol is well-dated and easy to recognize in late Holocene alluvial sections, it is a time-stratigraphic marker and can be used to estimate the age of cultural deposits contained in its horizons.

At some archaeological sites, the properties of surface and/or buried soils may be used to infer the age of cultural deposits associated with the soils. This

inference is possible because the degree of development of a soil profile or specific pedological features in a profile are indicators of time elapsed after deposition of parent material and, in some situations, as an approximate indicator of age (Holliday, 1990). Pedologic features that are time dependent have been summarized by Holliday (1990), and they include overall profile morphology, as determined by soil indices (Bilzi and Ciolkosz, 1977; Harden, 1982); profile thickness (Birkeland, 1999); illuvial clay content and reddening of the B horizon (Birkeland, 1999; Gile, 1979, 1985; Gile et al., 1981; McFadden et al., 1986); calcium carbonate accumulation (Birkeland, 1999; Gile et al., 1981; Machette, 1985; McFadden et al., 1986); clay mineralogy (Birkeland, 1999; McFadden and Hendricks, 1985; Shroba and Birkeland, 1983); and alteration or translocation of certain forms of iron, aluminum, and phosphorous (Birkeland, 1999; Birkeland et al., 1979; McFadden et al., 1986; Scott, 1977).

At localities with soil chronosequences and exceptional time control, it is possible to estimate rates for the development of soil profiles and for some pedological features. The Lubbock Lake archaeological site in the Southern High Plains of northwest Texas is an excellent example of such a situation. Holliday (1985c, 1988) defined a late Holocene chronosequence at the site. By combining field and laboratory data with the site's well-dated geochronology, he was able to determine rates of pedogenesis and, more specifically, time requirements for the development of diagnostic horizons in the Southern High Plains (Holliday, 1985c, 1988). This information has proved useful in dating soils and associated cultural deposits at other sites in the region (Holliday, 1989, 1990, 1995, 1997). Holliday (1990:531) cautioned that in comparing soils from site to site for dating purposes, the soils being compared must be in similar landscape positions and parent materials because both of these factors strongly influence soil morphology. He also stressed that stratigraphic relationships and archaeology must be considered because soils with similar morphology can form at different periods. It is also important to note that rates of pedogenesis vary among the bioclimatic regions of the world (see Birkeland, 1999). Hence, the chronosequence at Lubbock Lake cannot be used to estimate the age of soils far beyond the Southern High Plains.

In a recent Phase II testing of eight archaeological sites in the central Upper Peninsula of Michigan, Anderton (1999) used pedological information not only to determine the degree and processes of site disturbance, but to provide temporal context for the cultural deposits. The sites, which are associated with mid- and late Holocene paleoshorelines of the ancestral Great Lakes, contain stone flakes and fire-cracked rock but rarely yield diagnostic artifacts or datable carbon. Because of the association with dated shorelines, many researchers assumed the sites are Archaic occupations dating to ca. 5,000–2,000 B.P. However, later Woodland cultures (ca. 2,000–500 B.P.) may have also used the abandoned shorelines (Anderton, 1999). By considering the expected pedological and archaeological characteristics, Anderton (1999) developed a soil–artifact context model that provided a preliminary means of relative dating. Specifically, sites that were correlative with shoreline development (i.e., Archaic) have artifacts that are deeper within the soil profile, soil horizon boundaries that cut across middens, and some artifacts that are iron stained from Spodic horizon development. In contrast, sites that post date shoreline development (i.e., Woodland) have artifacts that are at or very near the ground surface. Also, Woodland cultural features, if present, cut across soil horizons, and the artifacts tend not to be iron stained.

5. Soils and Site Excavations

Site excavations require fine-scale analysis of soils aimed at addressing issues regarding site formation processes, paleoenvironmental conditions, and stratigraphy. It is usually at the excavation level of investigation that distinctions among pedologists, physical geographers, or geologists and true geoarchaeologists become most evident. The scale of interest in site excavations is much more refined than at the levels of archaeological investigations discussed previously, often being restricted to single landforms or portions of landforms. Archaeologists and pedologists generally feel most comfortable at this scale, whereas geomorphologists usually feel more comfortable addressing issues at the broader landscape scale. Because of the issue of scale, archaeologists must have a good idea of what information they want to obtain from a soils specialist during the excavation, and they must be able to clearly communicate those needs in order to ensure that the information gathered about soils is of sufficient detail to prove useful.

All other information collected during an excavation relies on proper interpretation and documentation of stratigraphic relationships within the site. As discussed previously, soils can provide essential information for recognizing stratigraphic breaks, recognizing periods of landscape stability, and tracing the lateral extent of geomorphic surfaces. The distribution of archaeological deposits, especially features and age-diagnostic artifacts, can contribute significantly to the recognition and tracing of soils, especially in settings where several weakly expressed soils are superimposed.

Excavations at the Main Site (15BL35), in the Cumberland Valley of southeastern Kentucky, provide an example of how soils and archaeological data were integrated during an excavation to provide a detailed stratigraphic framework for understanding a site buried in alluvium. An archaeological survey for a highway right-of-way recorded a portion of the site situated on a low terrace (T2). During the testing phase of this area, trenching revealed a much larger and more deeply buried site area that included adjacent portions of the floodplain (T1; Creasman, 1994). Excavations into T2 revealed a stratified site consisting of Early Archaic through Middle Woodland cultural horizons contained within the upper 1.2 m of the T2 fill. All the cultural horizons were contained within the Ap-Bt-BC profile of the surface soil. Detailed examination of the block excavations and consultations with the site archaeologists regarding the horizontal and vertical disposition of diagnostic artifacts allowed the site geoarchaeologist to recognize and map the distribution of a weakly expressed buried soil that marked a land surface that had existed on T2 from about 6300 to 3000 BP (Bettis, 1994). The buried soil was severely overprinted by subsequent development of the surface soil and was traceable only by combining soil morphology with artifact distribution data.

Below the buried soil, Early Archaic cultural remains were present, whereas the deposits above the buried soil surface contained archaeological deposits that were 3000 years old and younger.

Distinctly different soil and sediment stratigraphy were discovered beneath T1 compared to T2. The floodplain (T1) consists of a low natural levee paralleling the Cumberland River and a lower lying backswamp behind the levee and bordering T2. Archaeological deposits were encountered throughout the upper two meters of the T1 fill but were shallower and more concentrated in the area of the natural levee. Cultural horizons contained in the T1 fill represented early, middle, and late Woodland occupations that had focused on the slightly higher, better drained natural levee adjacent to the river. The Ap-A-Bw profile of the surface soil is developed throughout the upper 1.5 m of the T1 fill, and the Bw horizon is welded into two weakly expressed buried soils. Middle and Early Woodland occupations were associated with these buried soils, whereas the Late Woodland cultural horizon was encountered above the buried soils (Fig 7.7). Recognition and tracing of these buried soils allowed the investigators to correlate soil and natural stratigraphy and associated archaeological deposits between widely separated block excavations and accomplish mitigation of a large site in an efficient manner.

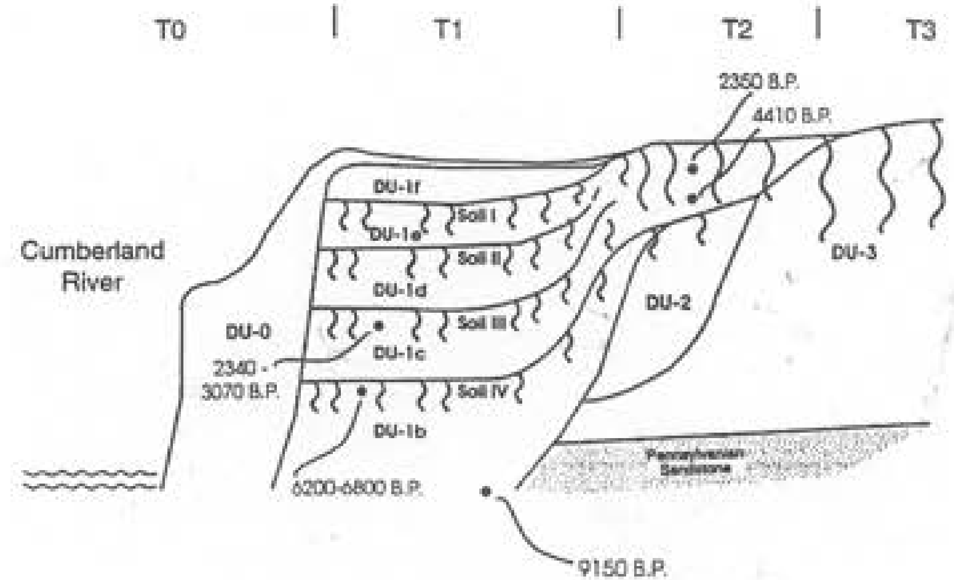

Figure 7.7. Idealized stratigraphic profile at the Main site (15BL35) in the Cumberland River valley of eastern Kentucky (from Bettis, 1994). Several weakly expressed buried soils beneath T_1 merge with the surface soil on T_2. Late Woodland cultural horizons were associated with alluvial deposits above Soil III in the T_1 fill, and Early and Middle Woodland horizons were encountered within and below Soil III. Early Archaic cultural horizons were found within Soil IV beneath T_2, and Middle and Late Archaic as well as Woodland horizons were encountered in the strongly expressed surface soil developed on T_2.

Site formation processes involve a host of natural and anthropogenic processes that combine to produce archaeological deposits (Schiffer, 1983, 1987). Soils can often shed light on the role of natural processes in the formation of archaeological deposits at a site, as well as provide important clues for interpreting the appearance of archaeological deposits in terms of human activity. Mixed soil horizons and thick biomantles point to processes that may have mixed or sorted artifacts and compromised the integrity of some archaeological deposits. Disrupted zones in soils point to major disturbances, such as tree throw, slumping, gullying, or pit digging that mix and destroy the integrity of cultural deposits and, in some cases, produce inverted stratigraphic sequences.

As noted earlier, rates and spatial patterns of sedimentation strongly influence soil morphology and stratigraphy in depositional environments. This is an important consideration during the excavation phase at some archaeological sites. A case in point is the Mahaphy–Akus–Denison (MAD) site (13CF101) in the Boyer River Valley of western Iowa. A Middle and Late Woodland midden was shallowly buried on a low terrace at MAD, whereas diffuse Middle and Late Woodland archaeological deposits were found at much greater depth in the adjacent lower lying floodplain (Benn, 1990). Several A–C soil profiles were present in the floodplain deposits, and these buried soils merged with the more strongly developed surface soil on the adjacent terrace (Fig. 7.8). Based on the soil-stratigraphic record, the late Holocene floodplain was a zone of rapid

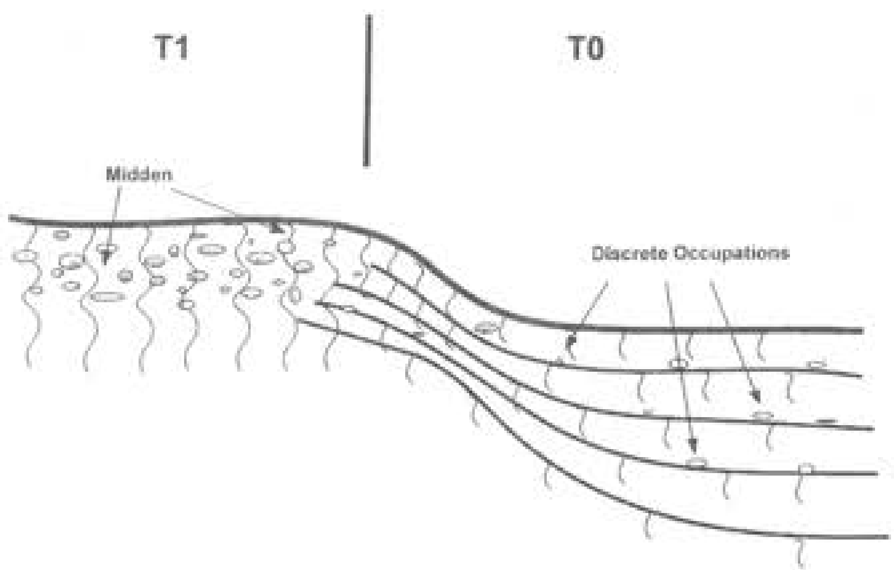

Figure 7.8. At one of the MAD sites (13CF102) in the Boyer River valley of western Iowa, discrete Woodland occupations were associated with weakly expressed buried soils beneath the floodplain (T_0). The Woodland people also inhabited the adjacent terrace (T_1), where sedimentation rates were lower compared to rates on T_0. Consequently, the discrete Woodland occupations observed in weakly expressed buried soils in the T_0 fill are represented by a single midden in a strongly expressed surface soil on T_1 (Bettis, 1990).

sedimentation punctuated by short episodes of landscape stability and pedogenesis. In contrast, the adjacent terrace was a zone of stability and soil formation throughout most of the late Holocene. There is strong evidence suggesting that the rates and spatial patterns of sedimentation during the period of human occupation at the MAD site greatly affected the appearance of the archaeological deposits. For example, the Woodland deposits buried in the floodplain often contained evidence of single residential units that had become subsequently buried, followed by evidence for yet another single residential unit during the next short episode of floodplain stability. Soil-stratigraphic evidence suggesting that the period during which the discrete visits represented in the floodplain area corresponded to the same period represented by the midden on the terrace suggested that the midden represented many episodes of site use by relatively small groups (hamlets) rather than intensive occupation by a large group (a village). Subsequent pottery analyses and radiocarbon ages supported this (Bettis, 1990).

One of the primary goals of archaeological research at a site is the reconstruction of the local and regional environment when the site was occupied or detection of environmental change at the time of site abandonment. Because certain soil properties and soil types are related to climate, archaeologists often turn to pedologists or geoarchaeologists to furnish paleoclimatic information. However, as Holliday (1990) pointed out, soils are probably of limited use for reconstructing climates in archaeological investigations. His reasoning was as follows. In general, soils are not sensitive to discrete climatic changes that may be culturally significant. Also, some climatic changes in the Holocene, the time period that interests most North American archaeologists, were of insufficient magnitude to be detected in the pedological record. Finally, soil properties related to the time factor often resemble those related to climate. It is also important to note that soils change at rates that are usually slower than people respond to a climatic shift.

Despite the limitations described above, soils can be useful in providing some general paleoclimatic and paleoenvironmental information. Soil properties that best reflect the effects of precipitation and temperature on pedogenesis are (1) overall soil morphology, (2) organic-matter and $CaCO_3$ content, (3) depth to leaching, and (4) the depth to the top of the carbonate or salt accumulation zone (Holliday, 1990). Micromorphological features of soils may also be used to infer paleoenvironmental conditions (Fedoroff et al., 1990)

Examples of using soils for paleoclimatic reconstructions at archaeological sites are provided by Reider (1980, 1982, 1990). He noted that soils at terminal Pleistocene archaeological sites in Wyoming and eastern Colorado are mostly Aquolls and Argialbolls with properties indicative of a generally cool, humid environment. In contrast, calcareous or alkaline soils (Calciustolls and Natrargids) at sites dating to the middle Holocene thermal maximum, the Altithermal (ca. 8,000–4,000 B.P.), were interpreted as evidence of significant climatic drying. Reider (1990) suggested that weak development in post-Altithermal soils probably reflects general landscape instability associated with fluctuating Neoglacial climates in the region. Caution should be exercised, however, when inferring regional paleoclimates entirely from soil properties, especially in alluvial settings.

Microenvironmental conditions, such as a perched water table associated with a poorly drained floodplain, can impart soil properties, including gley and carbonate accumulations, that may be incorrectly attributed to regional climatic conditions.

In a recent geoarchaeological investigation, Smith and McFaul (1997) used soil/sediment relationships and supporting geomorphic, paleobotanical, and paleontological data to reconstruct late Quaternary paleoclimates in the San Juan Basin of New Mexico. For example, they documented a strongly expressed buried soil with Stage II to Stage II+ carbonate morphology developed in eolian, alluvial, and playa sediments that were deposited during the late Wisconsinan. Radiocarbon ages suggest that development of this soil was underway by ca. 13,000 B.P. and continued until the soil was buried between ca. 9,300 and 7,800 B.P. Based on the strong morphology of the soil and the regional pollen data, they concluded that the late Pleistocene to early Holocene of the San Juan Basin was relatively moist. In contrast, buried soils that developed in eolian and alluvial sediments towards the end of the Altithermal (ca. 5,000–4,500 B.P.) are weakly expressed and have Bk horizons with Stage I to I+ carbonate morphology. Smith and McFaul (1997) attributed weak soil development during the mid-Holocene to aridity and concomitant landscape instability. They support this interpretation with pollen data and paleohydrological and glacial records for the region.

Soils may also harbor other types of paleoenvironmental information, such as a record of dominant vegetation in the stable carbon and oxygen isotopes (Baker et al., 1998; Cerling et al, 1989; Humphrey and Ferring, 1994; Monger et al., 1998; Nordt et al., 1994) and phytoliths (Fredlund and Tieszen, 1997). In addition, gastropods preserved in soils may yield information on precipitation and temperature trends (Baerreis, 1980), and micromammal remains in soils can provide a wealth of information on the environment as well as human diet (Adovasio et al., 1984; Semken, 1980; Semken and Falk, 1987).

6. Summary and Conclusions

In this chapter, we have shown how soils can and should be used in archaeological investigations. Although many studies have addressed soil science applications in archaeology, pedological information provided to archaeologists is often very technical and, therefore, difficult to apply in the field. This chapter takes a practical approach to soils and archaeology by (1) explaining why it is important for archaeologists to understand the difference between soil and sediment, (2) describing how to distinguish soil from sediment, and (3) discussing the type of soil information needed at different levels of an archaeological investigation.

Distinguishing soil from pedologically unmodified sediment is crucial to all archaeological field investigations. Soils consist of one or more horizons that differ from underlying sediment as a result of the interactions of parent materials, climate, living organisms, and relief through time. Soil horizons are products of pedogenesis, and they develop subsequent to the formation of the body of

sediment in which the soil occurs. Hence, soils reflect the passage of time for stable landscapes that supported and recorded human occupations.

During archaeological surveys, it is imperative that information concerning soils geomorphology is gathered early in the investigations. Specifically, knowledge of the temporal and spatial patterns of buried soils enables archaeologists to identify and target areas with high potential for buried cultural deposits. This information also may be used to assess certain aspects of the archaeological record, such as paucity of sites dating to a specific period.

Pedology is also an important component of site evaluations and, as with archaeological surveys, should be implemented during the early stage of investigations. Once the cultural deposits are placed in a soil-stratigraphic context, the potential depth and lateral extent of archaeological materials may be determined. Information gleaned from soils at a site also can be used to assess the integrity of the cultural deposits. Soils are very dynamic, and the various soil properties, factors, and conditions often determine the extent to which archaeological materials are preserved, modified, moved, or destroyed by postdepositional processes. In situations where absolute time control is absent, soils can be used to infer the relative age of cultural deposits. This can be accomplished through direct methods, such as dating the carbon in the artifact-bearing soils, or indirectly through correlation of soils or using data derived from soil chronosequences.

Soils can also serve as key stratigraphic markers for deciphering site stratigraphy and for correlating former land surfaces and human occupation zones. In addition, paleoenvironmental information gleaned from soils can be essential for better understanding the environment during site occupation, and it may provide insights on environmental changes that influenced human subsistence and settlement strategies.

In sum, soils are historical archives that, if interpreted properly, can provide archaeologists with a wide range of information for locating and interpreting archaeological deposits. With a general understanding of the potentials and limitations inherent in interpretation of soils, archaeologists can frame questions and research strategies that will yield important new information for interpreting the record of the human past.

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8

Microfacies Analysis Assisting Archaeological Stratigraphy

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1. Introduction

Accurate construction of archaeological stratigraphy has long been recognized as crucial in providing a solid chronocultural framework for discussing past behavioral activities and their linkages with geological processes (Gasche and Tunca, 1984; Harris, 1979). As a consequence, a major effort during excavation has been directed toward the definition of individual strata and their spatial variations. This goal has been accomplished through careful observation of the properties of the sedimentary matrix and its organization in three-dimensional space. The interfering effects of natural agents and human activities on the accumulation of the sedimentary matrix has been considered by some to conform to the principle of stratigraphic succession—as elaborated by earth scientists—and thus conforming to geological laws (Renfrew, 1976; Stein, 1987). Others have strongly argued that the rules and axioms of geological sedimentation cannot be applied to archaeological layers because they are produced by people and thus constitute an entirely distinct set of phenomena (Harris, 1979; Brown and Harris, 1993). Understanding the processes involved in the formation of archaeological stratification has also long been a question of passionate debate, with the views of human or natural deposition being opposed to the theory of biological mixing (Johnson and Watson-Stegner, 1990). These contradictory perceptions have been

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