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GUIDANCE TO IMPROVE ARCHAEOLOGICAL INTERPRETATIONS OF SOILS AND SEDIMENTS

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GUIDANCE TO IMPROVE ARCHAEOLOCIAL INTERPRETATION OF SOILS

1. Purpose.

a. This PWTB provides basic guidance to U.S. Army Cultural Resource Managers (CRMs) and their consultants on how to recognize and interpret soils in archaeological contexts. The ability to do so aids their understanding of archaeological sites, helps them make informed and proper management decisions about land use, and helps avoid expending funds to repair damage to important sites.

b. All PWTBs are available electronically (in Adobe® Acrobat® portable document format [PDF]) through the World Wide Web (WWW) at the National Institute of Building Sciences' Whole Building Design Guide (WBDG) Web page, which is accessible through the following Universal Resource Locator (URL):

http://www.wbdg.org/ccb/browse_cat.php?o=31&c=215

2. Applicability. This PWTB applies to all U.S. Army facilities CRMs and their consultants.

3. References.

a. Army Regulation (AR) 200-1, "Environmental Protection and Enhancement," 13 December 2007.

b. The National Historic Preservation Act of 1966 (NHPA) as amended (Public Law 89-665; 16 U.S.C. 470 et seq.).

4. Discussion.

a. This document should be viewed as a starting point for those who wish to expand their understanding of issues such as soil and sediment origins, horizons, descriptive terminology, and directions for more in-depth reading. Knowledge of the soil-related factors involved in archaeology will help a CRM better understand the needs for care of sites and for expert help when necessary.

b. The Army is responsible for millions of acres of land that involve a broad spectrum of geography and uses, both present and past. Knowledge of the land's previous uses and related archeological significance are the responsibility of each installation's CRM.

c. AR 200-1, Section 6 prescribes Army policies, procedures, and responsibilities for meeting cultural resources compliance and management requirements. The scope of AR 200-1, Section 6 compliance includes the NHPA; American Indian Religious Freedom Act and Executive Order 13007; Native American Graves Protection and Repatriation Act; Archaeological Resources Protection Act, 36 CFR 79; and other requirements and policies affecting cultural resources management.

d. The NHPA requires federal agencies to take into account the effect of their undertakings on any district, site, building, structure, or object that is included in or eligible for inclusion in the National Register of Historic Places (NRHP). Compliance with the NHPA and AR 200-1 typically requires the agency to identify historic properties within an area that may be impacted by an undertaking and to evaluate those properties' eligibility for nomination to the NRHP. In the case of archaeological sites, this evaluation often includes excavations designed to define a site's boundaries and to assess its integrity and historical and cultural significance relative to one or more historic contexts.

e. Despite the relevance of soils to archaeology, many professional archaeologists have little or no formal training in soil science. Too many archaeologists refer to all forms of the geologic matrix of an archaeological site as "soil," not making a distinction between soil and sediment. Some also use the two terms interchangeably or substitute the even more colloquial term "dirt."

f. Appendix A discusses factors that affect the formation of the soil's "A horizon."

g. Appendix B explains factors that contribute to subtle distinctions in the soil's strata.

h. Appendix C focuses on how field personnel can interpret strata as one aspect of the process to evaluate a site's historical integrity, significance, and research potential.

i. Appendix D discusses color versus texture criteria for determining soil horizons.

j. Appendix E is a brief overview of common chemical tests of soil which are used to provide a better understanding of a site's past use.

k. Appendix F lists references used in preceding appendixes.

l. Appendix G is a list of abbreviations used and their spelled-out meanings. A glossary of geoarchaeological terms also is included.

5. Points of Contact.

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Appendix A

FACTORS AFFECTING FORMATION OF THE A HORIZON

Definition of Soil

To farmers and agronomists, “soil” is a medium in which plants grow (Holliday 2004, 2). But to engineers, many geologists, and associated specialists, all soil is unconsolidated sediments including loose or weathered rock. Soil scientists and geoarchaeologists, however, have a different, more specific definition that will be used in this appendix and is widely used in geoarchaeology. This more specific definition of soil is:

> … a natural three-dimensional entity that is a type of weathering phenomenon occurring at the immediate surface of the earth in sediment and rock… and the result of the interaction of the climate, flora, fauna, and landscape position, all acting on sediment or rock through time. (Holliday 2004, 3)

A few key points can be taken from this definition. First of all, soils are weathering phenomena that occur *within* pre-existing sediments or rock.

- The different soil strata within a soil profile are not laid down at different periods as are sediments, but form out of pre-deposited sediments or rock.

- The visual and textural distinctions observable among soil horizons (zones within the soil that parallel the ground surface and have distinctive physical, chemical, and biological properties [Holliday 2004,3]) that are the result of the movement of chemicals and soil particles within the sediment.

- This process of soil formation (pedogenesis) takes time, and the nature of soil development at an archaeological site can provide the archaeologist with important information about the site, its antiquity, what types of artifacts will and will not likely be recovered, and what kinds of disturbances may have disrupted the site and to what degree.

- Soils require stable land surfaces to form, meaning that the surface of a soil has more time to accumulate traces of human occupation than does an unstable non-soil nearby (Mandel and Bettis 2001, 175).

Soils appear in the archaeological record as differentiated layers of material that contrast in color, texture, structure, and chemical composition. Making distinctions among layers based on color and texture will be addressed in Appendix D.

The second point to take away from the definition of soil is that the formation of a soil is conditioned by a suite of factors, including:

- surrounding florae and faunae
- the local landscape
- ambient climate
- underlying geologic parent material from which the soil has developed

Given time, these factors shape the formation of various soil strata. The emergence of distinct A and B horizons (Table A-1) involves the movement of chemicals and particles within soil.

Definition of Sediments

Sediments, by contrast, are different strata (layers) deposited one on top of the other at different periods of time. Soils form within a single sedimentary deposit or rock, whereas sediments are formed from multiple depositions of material. Schiffer (1987, 200) suggests that archaeologists should refer to all “dirt” as sediment unless it can be conclusively identified as a soil.

Sediments form through a number of mechanisms, but have not gone through in-situ weathering, as mentioned. Sediments form from materials weathering in one place, which then move as solid particles or dissolved chemicals to accumulate in another place. This transportation may be driven by wind, flowing water, wave action, glaciers, or gravity-driven downslope movement. Once settled, soils form within these sediments.

Definition of Strata

Strata within a soil profile are named based on their different characteristics. A set of conventional terms for different soil horizons is shown in Table A-1. Following Vogel (2002), these horizons are arranged shallowest to deepest.

Table A-1. Strata within a soil profile, from shallowest to deepest (Vogel 2002)[1].

Strata	Characteristics
O horizon	Layer of decomposing organics that overlays but is not dominated by mineral inclusions. Organics could include things such as leaf litter or pine needles decomposing into a mat of material that is usually loosely constituted
A horizon	Mineral horizon formed at the surface or under the O horizon that is rich in organics. When disturbed by plowing, it is referred to as an Ap horizon.
E horizon	Mineral horizon formed beneath some O and A horizons. They are light gray color and usually of sandy texture.
B horizon	Mineral horizon where chemicals and nutrients collect as they are leached out of the O and A horizons. Sometimes referred to as “subsoil.”
C horizon	Horizon between the B and R horizons that is distinct either visually and/or chemically from both. This is the portion of the original sediment that has either not been affected by pedogenesis, or has been only minimally-impacted.
R horizon	Also known as bedrock. It is termed the “R horizon” because bedrock is sometimes referred to as “regolith.”

These different horizons appear as layers in the soil, commonly known as “strata.” The vertical sequence of strata, whether in soil or sediment, is referred to as the stratigraphy of that site. The two-dimensional representation of that stratigraphy, either in a map or in the vertical face of an excavation unit, is known as the stratigraphic profile. One of the vital parts of the field notes for a site is a record of its stratigraphy, as represented in the wall of an excavation unit. This stratigraphic profile is crucial for understanding the sequence of events that have affected a site since its formation and can be quite complex. Harris (1979) offers a useful methodology for

[1] Birkeland (1999) draws more subtle distinctions and subsets of these horizons, based on specific physical or chemical properties. Being able to distinguish between and describe the differences among Bt, Bw, and Bz horizons is both useful and necessary for soil specialists and archaeologists, but exceeds the intended scope here. Appendix B elaborates on this system of groupings.

clearly and systematically recording and interpreting site stratigraphy.

Like soils, sediments also can appear as layers contrasting in color and texture, although the boundaries between sedimentary layers are usually much sharper and clearer than between soil layers.

Familiarizing yourself with the basic A-B-C horizon system (as well as the O, E, and R horizons and finer gradations that are presented in Appendix B) provides a consistent means of communicating soil information. Because the different horizon definitions are quite specific (Figure A-1), using them in a report of archaeological fieldwork is an effective way to relate to those who were not present at the excavation what you saw during excavation and what that means about the history and taphonomy (post-burial changes) of the site. That ease of communication is important for conveying findings to peers and also for creating a historical record that future archaeologists may consult long after projects are completed.

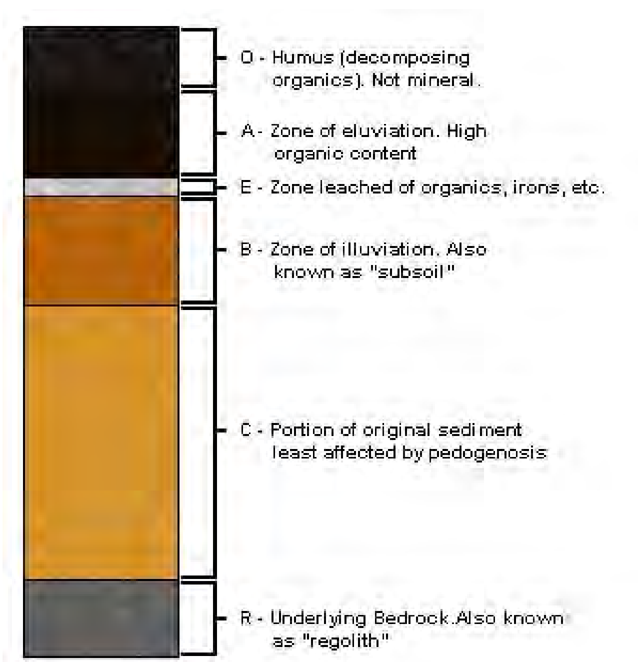

Figure A-1. Soil horizons.

One Stratum: Formation of the A Horizon

This appendix deals with the formation of the A horizon because the A horizon is the stratum which contains many different kinds of archaeological information. Being derived from the surface of a stable landscape, one that is conducive to human occupation, the A horizon is the most important one in terms of preserving both artifacts and the spatial relationships that connect them. Though the O horizon overlays it, the O horizon is primarily made of decomposing plant litter and is not as stable as the mineralized A horizon. That said, there are factors that bear on the formation of the A horizon that need to be taken into account during archaeological investigations. Knowing the conditions that affect the formation of the A horizon will not only inform the archaeologist about what artifacts may or may not have been preserved, but will also suggest how pedogenesis may have altered spatial and stratigraphic relationships over time. These variables affect how we interpret archaeological sites and how, as a result, we understand the past.

The A horizon is the uppermost mineral horizon. Rich in organics, it differs from the O horizon in that its organic material is represented in fine particles or as coatings on mineral particles. In the O horizon, by contrast, organics reside in a decomposing mat that retains characteristics of the materials (usually leaf litter) from which it is formed (Chesworth 2008, 669). As the materials in the O horizon further decompose into smaller-sized particles, they are washed downward and become part of the A horizon (Stein 1992, 196).

When an A horizon has been disturbed by cultivation, it is referred to as an Ap or Apz horizon (formed by abbreviation for “plowzone” or “plow zone”). There is a long-standing debate about the utility of archaeological materials found in Ap/Apz horizons, as some argue that plows displace artifacts, thus removing them from their original archaeological context, rendering them of little use (Noël Hume 1982). Others, particularly in historical archaeology, have been slower to cast aside plow zone material (King and Miller 1987). Findings from O’Brien and Lewarch (1981) suggested that plowing is less detrimental to horizontal integrity than vertical integrity. Based on their findings, King and Miller then used “nearest neighbor analysis” to identify middens and date different parts of the 17th century Van Sweringen Site in St. Mary’s City, Maryland. This type of success with plow zone archaeology should be remembered when working with sites that have been impacted by similarly disruptive activities, including bulldozing.

Four processes create soil horizons within sediments, which are considered internal changes. Simonson (1959, 153) offers one of the earliest, most succinct explanations of these four processes:

> Horizon differentiation in soils is considered due to four basic kinds of changes. These are additions, removals, transfers, and transformations in the soil system… Organic matter is added to the soil in the form of fresh residues. It is transformed and lost through decay. It may be transferred from one horizon to another.

These four simple processes (additions, removals, transfers, and transformations) create the strata seen in soils encountered during archaeological research. For example, as the O horizon breaks down (transformation), the resultant organic material is added to the A horizon (addition), which loses both organics and other chemicals to decay (removal) and to translocation, either laterally or vertically through the movement of water through the soil (transfer).

A and B horizons form in opposition to one another, as the B horizon is the recipient of the nutrients and minerals that move out of the A horizon through transference. This removal (eluviation) from the A horizon and deposition (illuviation) into the B horizon differentiates those two layers. The C horizon is that portion of the original sediment that the four soil-forming processes largely do not affect.

The four internal processes are conditioned by five external factors (Waters 1992, 53):

- the duration of weathering,
- the local climate at the time of soil formation (pedogenesis),
- the parent material from which the soil was formed,
- the overlying vegetation (as a contributor of organics), and
- the local landscape surrounding the soil (topography).

The CLORPT Model

The soil-forming factors just mentioned are essentially the "CLORPT formula" developed by Hans Jenny (1941, 1980). The formula is an equation that expresses soil (S) as a factor (f) of climate (cl), organisms (o), relief/landscape (r), parent material (p), and time (t). Jenny wrote this equation as

$$S = f(cl,o,r,p,t,\ldots)$$

Neither Jenny nor other soil scientists who have attempted to revise the equation have perfected it as a conceptual model (hence the ellipsis in the equation), but it has been one of the most robust and enduring of the various models advanced to explain pedogenesis. The CLORPT model is still the dominant approach to discussing soil formation; it appears in many handbooks and guides to geoarchaeology (e.g., Holliday 2004 and Vogel 2002). The CLORPT model will be used as a template for the rest of this appendix. (See Holliday [2004, 41-52] for discussion of alternative methods.)

Understanding how the different components of the CLORPT formula affect soil formation aids archaeological interpretation by giving the archaeologist an idea of how the soils encountered during excavation developed, what kinds of plant and animal communities the soil likely supported in the past (giving a window on diet), and what kinds of artifacts may be well preserved, and what may have disappeared long before excavation.

Climate (cl)

The local climate affects pedogenesis through two major variables: rainfall and temperature. Temperature affects humidity, evaporation, the growing season, the composition of vegetation, and the formation of microclimates, all of which bear on soil formation. The amount of rainfall influences the quantity of vegetation and the amount of eluviation that takes place within a given soil column. Eluviation is the movement of water-borne material downwards through the soil column. A more specific term, “leaching,” exists to describe the movement of materials in solution (Bunting 1967; French 2003, 37; Holliday 2004, 44).

Cool, wet environments inhibit biological action, commonly resulting in peat bogs (histosols). Peat bogs are highly organic, waterlogged soils that accumulate organic matter faster than the resident biota can break them down. These bogs form in cool environments such as northern Canada and Alaska, though they are also found in northern Wisconsin (Goldberg and Macphail 2006, 58).

In Alaska, peat bogs are known as muskeg, a corruption of a Native American Cree word for “low lying marsh.” When thawed, muskeg may be an unstable ground surface, as northern folklore records that a muskeg bog once swallowed a locomotive that was travelling tracks laid across the bog in northern Ontario. Muskeg is frequently dominated by sphagnum moss, which can hold many times its weight in water.

Since muskeg/peat is not a stable land surface, it is unlikely that people lived on them, meaning that habitation sites of any sort would not be found in them. This does not mean that they lack archaeological potential, however. Their ability to preserve organic material is remarkable. The most celebrated finds yet uncovered in peat bogs are the “bog bodies” found in Europe. The tannic acid found in bogs there essentially turned these bodies, dating to around the time of the Roman conquest, into leather, and provided remarkable preservation of skin and internal tissues (Glob 1977). No such finds are noted from northern North America, and archaeologists interested in, for instance, the peopling of the Americas through Beringia see muskeg bogs as hindrances in archaeological work, not fruitful excavation possibilities (Haynes 2006, 256). Still, the presence of peat or muskeg bogs in the United States could be taken as barriers to habitation, which could assist in the reconstruction of traditional land-use practices and social divisions of a regional landscape.

Arid environments evaporate water too quickly to support sufficiently large biological communities and, thus, do not generate strongly developed soils. Given a long time in specific conditions, arid soils can form argillic horizons (see section on Time). Extremely arid environments can create false stratigraphy because water carrying dissolved carbonates, salt (halite), and gypsum evaporates out of the sediment, leaving bands of these minerals behind below the surface. While not an example of actual pedogenesis, such banding in buried sediments can be taken as evidence of arid conditions in the past, which can aid the archaeologist in paleoclimatic reconstruction (Goldberg and Macphail 2006, 70).

Arctic areas generally do not produce strongly developed soils because cold temperatures do not support biological communities that break down sediment into soil (see sections on Flora/Fauna and Time in this appendix).

The deepest, most active soils are found in areas that are both damp (high precipitation and humidity) and warm (high average annual temperatures). Sub-Saharan Africa and the Amazon rain forest, both of which fit these criteria, are both known for their deep soils (Goldberg and Macphail 2006, 58). The deepest soils in the United States may be found in the lowland South and Midwest, particularly in the Mississippi and Missouri River Valleys. Eluviations and leaching in these soils tend to be deep, leading to the formation of substantial A and B horizons.

Some soil scientists see climate as the most influential of the soil-forming factors because of its influence on the abundance and variety of plant and animal life (Birkeland 1999, 268).

Proponents of this idea frequently point out that comparing soil and climate maps reveals that certain types of soils simply do not appear outside of common climatic areas. This would tend to suggest that climate does bear significantly on what kinds of soils form. A strong relationship between climate and soil makes examining soils, particularly buried soils that are no longer undergoing active pedogenesis, an effective means of modeling long-term climatic change, which in turn affects the resource bases that people in the past would have confronted.

Organics (o): flora and fauna

The plants and animals (flora and fauna) that live in and above soils affect the formation of soil. Such organics are among the earliest of the five CLORPT factors to have a significant pedogenic impact upon newly deposited sediments, though the kinds of florae and faunae that will take up residence in a certain soil is a function of other soil factors, particularly parent material and climate.

The first organisms to move into a sediment are also the smallest. Lichens, algae, fungi, and mosses will colonize initially, followed by different varieties of grasses, then bushes and shrubs, followed by trees. Among tree varieties, coniferous forests will establish themselves first, followed by deciduous, hardwood forests (Goldberg and Macphail 2006, 58). Rotting plant material leads to the formation of humic and fulvic acid, which acidify the soil and move iron molecules downward, helping form soil horizons.

In addition to affecting soil properties of the A horizon and its other properties such as structure, texture, and porosity, plants on the surface serve as a binding agent, inhibiting erosion. Their root systems hold the topsoil together. The resulting stability in the Earth’s surface aids soil development over time (French 2003, 16) and helps provide a stable landscape for settlement and habitation.

Decomposing plants are also a major source of organic material from which O and A horizons emerge. These decomposing materials consist primarily of carbon, oxygen, and nitrogen, and the rate of decomposition is determined by the level of nitrogen in the dead plant material. Grasses, which are high in nitrogen, break down much more rapidly than deciduous forest litter, which tends to be lower in nitrogen (Goldberg and Macphail 2006, 58).

General trends in the way plant communities affect soil formation do exist, provided climate is held constant. Under grasslands, organics remain high in the soil column, and water is retained better than in forest soils (Goldberg and Macphail 2006, 51).

Whereas plants affect the soil by manipulating its structure and contributing organic material, the chemical makeup of the soil affects both historic and contemporary landscape-level plant communities. Archaeologists have found certain phenomena to be reliable indicators of ancient vegetation regimes. For instance, the presence of a podzol (an ash-grey E horizon overlying a darker B horizon) is generally associated with forest soils, while a calcic Bk horizon rarely forms in acid-rich forest soils (Holliday 2004, 202). Within forests, the organic matter depth, saturation, and pH can all vary, both with the type of tree that is locally dominant (coniferous vs. deciduous) and the distance from the nearest tree. These variances occur because the tree canopy inhibits rainfall on those areas nearest it (Birkeland 1999, 268).

Holliday (1987) used soil stratigraphic evidence to interpret past climates at Blackwater Draw, New Mexico. This site is the first place that Clovis materials (the earliest widely-accepted proof of American settlement) were encountered. Pollen studies suggested that the area was forested at the time of habitation (Wendorf 1961, 1970; Wendorf and Hester 1975). This is significant because, to support forest growth, the area would have needed to be much wetter and cooler than it is now. Holliday countered Wendorf’s arguments by showing there was no evidence of forestation in the soil record. The lack of evidence for podzolization (see Appendix B) indicated that there was no significant history of forestation, and that conditions in the past were warm and dry, similar to present-day eastern New Mexico. This was part of a significant archaeological discussion concerning the spread of wooly mammoth populations during the Clovis period. If eastern New Mexico’s climate today is much like it was then, then the wooly mammoth herds on which Clovis people preyed would have lived in more varied ecological conditions than would be suggested if the site in antiquity had been a cooler, more heavily-forested area.

Understanding plant-soil interactions can facilitate modeling past climates, which affected how people used and manipulated the land on which they lived. Differentiating podzols from mollisols not only helps the archaeologist understand past vegetation communities, it can point towards likely differential preservation conditions for different kinds of artifacts. Strongly acidic soils have been documented to be more damaging to materials such as bone than neutral or even weakly acidic soils (Gordon and Buikstra 1981). The same can be said for metal artifacts (Gerwin and Baumhauer 2000).

Large animals (rodents and larger) tend to disturb soil structure through burrowing. The decomposition of their corpses and bodily wastes, however, adds organic materials to the soil (see Faunalturbation in Appendix C).

Smaller animals, particularly earthworms, have important roles in pedogenesis. Earthworms consume and excrete soil particles, breaking them down into finer pieces, aerating the soil, and mixing the nutrients. Most earthworm activity takes place within 20–40 cm of the surface. Soils that have been heavily worked by earthworms will likely have a granular structure, whereas soils that have not been heavily affected tend to be typified by angular blocky structure (Mandel and Bettis 2001, 177-178). The consumption, digestion, and deposition of soil particles by earthworms help to churn organic material from the O horizon into the A horizon (Goldberg and Macphail 2006, 58).

Recent invasions by non-native earthworm species, particularly Asian and European varieties, have accelerated nitrogen mobilization and leaching, particularly near urban areas where landscaped yards frequently serve as points for invasive species introduction (Szlavecz et al. 2006). These imports have all arrived since European settlement began. Some states, such as Minnesota, do not have native earthworm species due to past glaciation, meaning all encountered earthworms are invasive (Minnesota Dept. of Natural Resources 2009). These invasive species are currently radiating out from urban areas into the countryside. The effects of this change have yet to be fully studied, though the damaging effects in northern forests have already been reported (Hendrix 2006).

Relief/landscape (r)

The shape of the landscape affects how sediments are deposited (and by extension where soils develop), soil thickness, altitude, and the way people use soils. Soils are thinnest on top of hills and mountains because gravity and erosion pull sediments downslope. Areas at the bases of hills and in valleys where sediment accumulates are therefore the places where soils are deepest. They also receive the most run-off water from the hillsides and have the best natural irrigation, which promotes leaching and eluviation of clay and other materials between soil strata.

The A horizons are less likely to develop on the unstable, eroding surfaces of hilltops, whereas conditions at the bases of hills are more conducive. Also, the A horizons will be thicker and deeper in areas favorable to the accumulation of sediment than in areas with thin sediments.

People acting upon the landscape can affect pedogenesis in a number of ways. Human control of vegetation communities, through clearing and cultivation, incurs the effects mentioned above (see Organics section) for floral impacts on pedogenesis. Removal of plant cover can promote erosion of soils and sediments. Digging, plowing, and other invasive practices disrupt the soils, thereby affecting the progress of pedogenesis. Additions of some chemicals and nutrients through the application of fertilizers, and the removal of others through cultivation will affect the chemical composition of soils (Courty et al. 1989, 104-137).

Deep, thick soils in river valleys and other low-lying areas are, and have long been, the most fertile agricultural soils, and have served as magnets for habitation over the millennia. More fertile soils, both today and in antiquity, will frequently be more intensely farmed. Being able to read the landscape and understand the connection between topography, soil characteristics, and settlement preferences will be an aid for predicting site locations. Knowing how people used different soil bodies across the landscape in the past will be an aid to CRMs, as knowing what kinds of landform would have been the most heavily used in the past will suggest where archaeological sites are likely to be most abundant, and where site preservation concerns will likely be most acute.

Parent material (p)

Parent material has a strong impact on soil characteristics, including chemical makeup, because weathered parent material is one of the main elements of a soil’s mineral content. Climate and vegetation also play a role (i.e., formation of E horizons under forests). The chemical composition, physical characteristics, and particularly the pH of parent material(s) determine what soils could develop. For example, soils formed from acidic igneous rock will be acidic and produce quartz crystals. By contrast, basic igneous rock gives rise to basic soils that, instead of generating quartz, produce clay and minerals that are rich in iron and magnesium. Sandstone produces sandy soils, which are well-drained but are prone to lose nutrients (French 2003, 36-37).

As the parent material conditions what kind of soils can develop, it therefore determines, to a considerable extent, the preservation of artifacts and ecofacts held in that soil, the kind of humus that will form, and even the kinds and intensity of bioturbation that take place in a given soil type (Goldberg and Macphail 2006, 60). Acidic soils, for instance, form from acidic igneous rock, acidic sands, and schist; support communities of mites and non-burrowing (litter-dwelling) earthworms; and best preserve pollen and botanicals. Basic soils, on the other hand, form from chalk and shell-rich sand, support restricted populations of slugs and burrowing earthworms, and best preserve mollusks and bone (Goldberg and Macphail 2006, 47). Like vegetation, the chemical makeup of the soil heavily shapes the preservation conditions within the soil matrix. Schiffer (1987, 148) notes that soils which hold water promote chemical reactions that can hasten artifact degradation. Acidic soils break down bone, as was noted above, while basic soils degrade pollen quickly.

Schiffer (1987) stresses that the various environmental characteristics that promote or inhibit degradation of artifacts are very locally specific, and one must look at soil chemistry, water saturation, and the presence of other factors (sunlight, salts) that affect preservation conditions.

A number of field methods are used for estimating acidity/ alkalinity. For example, the appearance of an E horizon in the soil profile is generally indicative of acidic soils, though the thickness of the E horizon is not an indicator of the degree of acidity. This means that high acidity does not necessarily produce a thicker E horizon, but neither does a thin E horizon mean lower acidity. Time and other factors can come into play.

Field testing for pH is the most direct means of determining pH, and is sufficiently accurate to class soils as alkaline or acidic. Field testing is done by moistening some soil with distilled water (do not handle the sample), and touching a piece of litmus paper to it. Acidic soils will turn the paper red, alkaline soils will turn it blue. Strips of litmus paper are available for a nominal cost from most scientific supply companies (currently $2 for 100 strips).

Time (t)

Development of soil horizons, known as horizonation, takes time. The longer a soil horizon has to develop, the better expressed it will be. The formation of the A horizon is primarily the result of two competing processes: the accumulation and the decay of organic materials (Birkeland 1999, 107-108). Organic material originates in the decomposition of floral and faunal remains on the surface of the soil. This addition of organics enables the soil to support more organisms (worms, bacteria, fungus) that break down the organic material. Given constant accumulation of organic material, the number of organisms the soil supports will hit a steady state, which keeps the organic content of the soil at a fixed point of equilibrium (Stein 1992, 200). The longer the soil has to form, the more likely it is that this equilibrium will form, though the process typically takes between 2,000 and 10,000 years (Birkeland 1999). Mere appearance of strata can start much earlier, of course. Controlled experiments documenting changes in soils can be seen in as little as 32 years following sedimentation (Goldberg and Macphail 2006, 62).

Pedogenesis takes time, but the amount of time required is not the same across all soil forming processes. Several attempts have been made to date sites based on the “maturity” of the soils in which they were found, though with little success. Dimbleby (1962, 62 [cited in Goldberg and Macphail 2006]) found gathering Carbon-14 (also expressed as ^{14}Carbon, ^{14}C, or C-14) dates from the soil humic fractions to be a more useful dating technique.

A few general rules relate soil development strength to pedogenic processes. For instance, processes that involve the accumulation of materials develop much more rapidly than do weathering processes. Regionally, soils form slowest in the interior of Antarctica, where the lack of vegetation and cold climates inhibit the formation of soils. The frigid temperatures inhibit chemical and biological weathering processes in the soil, and frequent permafrost conditions inhibits the ability of moving water to translocate clays and other minerals within the soil column. Also, the lack of substantial plant communities means there is no regular accumulation of organic material to help build an O or A horizon. Formation of clearly delineated soil horizons may take 3.5 million years or more (Birkeland 1999, 183).

Several geologists have attempted to model the rate at which soil formation occurs in a few highly bounded locations. By examining soils formed under conditions that only vary in age (having identical climate, parent material, organics, and landscape); variations in soil thickness can be taken to be strictly the result of duration of pedogenesis. Comparative deposits are usually selected within restricted geographic regions, as the need to control for everything save time requires all sample soils to have formed under identical conditions, which seldom occur over larger areas (Holliday 2004, 162). These studies, termed “chronosequences” exist for several areas of the United States. Archaeologists should be familiar with any documented chronosequences in the areas they are working, as understanding the age of a soil can be an important aid to finding, dating, and predicting sites. Historic sites are not likely to be found in undisturbed soils that required 20,000 years to form. Though there is not a central clearinghouse for chronosequences in the United States, Holliday (ibid.) provides a partial list of those available.

Ages for buried soils can be directly calculated using absolute dating techniques applied to carbon found in the soil. Pedogenic processes, particularly the movement of materials as a result of earthworm action, cycle carbon through the soil column, particularly in the upper 20-40 cm. Dating a single A horizon by using C-14 analysis should use multiple samples from the same stratum, but drawn from different depths within it. Averaging the resultant dates will give an idea of how old a soil is, but one should be careful to avoid placing too much emphasis on C-14 dates for soils, as they by nature contain a degree of error and variation (Waters 1992, 82). Still, particularly for buried soils, C-14 dating can provide an idea of the antiquity of the deposit and associated cultural materials. Special care needs to be taken not to sample old soils where modern roots have penetrated.

Sand presents different pedogenic conditions. Sand dunes younger than 100 years lack soil. Older sands form clay-enriched bands called lamellae that form between 100 and 4,000 years of age. They will initially appear as multiple thin, discontinuous lamellae, but slowly, through the accumulation of clays, will form into thicker bands of clay particles. This usually takes place after 4,000 and before 7,000 years of stable conditions. By around 10,000 years old, these clay particles will form into a single horizon. Though commonly found in deserts, such banding can occur in sandy soils in cooler, wetter conditions (Birkeland 1999, 191).

Time is unlike the other processes listed above in that it does not itself produce changes. Rather, the more time allowed, the greater the effect of the other factors and the more thorough the development of the soil. If given enough time, pedogenesis may actually slow down, as the soil becomes fully formed and reaches equilibrium for its various processes (French 2003, 38).

Time can be an important clue to archaeological interpretation. As robust, clearly defined horizons take time to develop, it is unlikely that a very recent site will be found within a well-developed soil column (bearing in mind the distinction between soils and sediments). Conversely, a site of great antiquity will probably not be found in a weakly developed soil that recently formed.

Appendix B

FACTORS CONTRIBUTING TO VERY SUBTLE STRATIGRAPHIC DISTINCTIONS

Most archaeologists are familiar with the A, B, and C horizon designations used in soil analysis mentioned in Appendix A, as these are frequently encountered in field work and reports (bearing in mind the distinction between sediment and soil, also mentioned in Appendix A). Fewer archaeologists recognize subdivisions of these master horizons or the less-frequently encountered E, O, and R horizons. This appendix provides a brief description of the master horizons used for soil descriptions in the United States, then describes subdivisions of those horizons, provides criteria for differentiating both horizons and subdivisions, and offers guidance on how to identify these entities in the field.

The following will offer some theoretical instruction regarding the different classifications that may be made, though true practical mastery of the skill of soil identification requires hands-on (or hands-in) fieldwork, preferably under the supervision of one trained to make such identifications in the field. Many universities and community colleges offer soil identification classes and workshops, and some state archaeological and geological surveys employ specialists in this area who could give insight and instruction. Vogel (2002) and other useful introductory guides to soil identification are available for those willing, or required to, travel the path of self-instruction. Birkeland (1999), Holliday (2004), and Goldberg and Macphail (2006) all contain descriptions of the horizon subdivisions listed below.

Being able to describe and record these finer horizon classifications in the field is a valuable archaeological skill, as greater specificity permits greater clarity in communicating archaeological observations to others, and helps archaeologists understand the site formation processes that structure any given site. Recording these observations not only facilitates communications between archaeologists, it creates a durable historical record of archaeological data that can be used in the future by archaeologists who may not have been part of the original project, and may not have access to the people who had done previous work. Recognizing and recording accurate and precise soil profiles is therefore a crucial part of archaeological excavation.

O Horizon

The O horizon lies above the topsoil and is an integral part of pedogenesis. It comprises decomposing biological material and the excreta that soil fauna leave at the surface as they churn the soil in the A horizon. As the materials of the O horizon become fully broken down, they form the upper levels of the A horizon. While both are rich in organic matter, the A horizon differs from the O in that it is a mineralized stratum, whereas the O is still primarily vegetation. Within the O horizon, there are finer descriptive gradations that may be used for greater specificity. These gradations subdivide a continuum of organic decomposition, which is inversely proportional to biological activity. The least broken down plant materials are the most biologically active. The O horizon is similar in organic content to the A horizon, but its preponderance of plant material differentiates it from the mineral A horizon.

Fibrous content estimations required for differentiating the various kinds of O horizons are made by rubbing a sample of a layer between the fingers. The soil portion should drop away, leaving behind decaying plant matter. The percentage of the original sample remaining after the soil falls away is the percentage of fiber content. Its character may vary, as described in the next subsections.

Oi Horizon

The Oi horizon contains the least broken down plant material. Birkeland (1999, 5) lumps all parts of the soil column that are more than 40% fiber content into the Oi horizon. This will be the uppermost, least-decomposed stratum of the soil column. It is, essentially, a stratum formed by an accumulation of plant fragments (Goldberg and Macphail 2006, 48).

Oe Horizon

Greater degradation of plant material marks the boundary between Oi and Oe horizons. As was the case with the Oi horizon, an Oe horizon is primarily plant litter, though it has lain around long enough for pedogenic processes to begin working on it. Soil fauna (worms, etc.) have begun to mix soil (excreta) onto it, and it has degraded into a thicker, more soil-like mat. It is between 17% and 40% fiber content at this point (Birkeland 1999, 5). Being rich in organic material, it is, like the other layers of the O horizon, dark brown in color.

Oa Horizon

This is the last stage in the transition of leaf litter into the A horizon. Fiber content for the Oa horizon is less than 17%. It is the most decomposed layer in the O horizon. Biological activity in the Oa horizon is very restricted, as the bulk of decomposition has already taken place.

Peat bogs are considered to be Oa horizons. They are masses of highly decomposed plant material, and are saturated with water. They are found in wet, cool environments such as the United Kingdom or parts of northern North America (see earlier discussion of muskeg). They are not mineralized and therefore cannot be classed as A horizons (Goldberg and Macphail 2006, 48). Peat bogs and muskeg offer uniquely advantageous preservation conditions for organic artifacts, particularly wood and soft tissue from humans and animals.

A Horizon

The A horizon is formed from accumulated decaying organic matter, original mineral sediment, and illuviational material. As is the case for all soil strata, a stable land surface is required for the formation of a clear A horizon. The A horizon is rich in organics, usually dark in color, and (unlike the O horizon) is predominantly mineral. This site is where most soil fauna live and is the zone where aeration and oxidation take place. It tends to be rich in nitrogen, phosphorous, and potassium. It is sometimes referred to as topsoil.

Vogel (2002) notes that, while the A horizon is largely leached of clays and minerals, quartz crystals may remain, being more resistant to leaching. Where high quantities of quartz are present, the A horizon could be lighter in color than underlying strata.

Ap (Apz) horizon

The only major subcategory of the A horizon is the Ap horizon, sometimes referred to as the Apz horizon. Ap horizons are ones that have been churned and mixed by cultivation. They have, in principle, been mechanically homogenized through mixing by plowshares. Exposure to the elements enhances oxidation. Odell and Cowan (1987) conducted controlled studies on the effect plowing has on artifact distributions. They found some displacement of artifacts in the direction of plowing, which can lead to spurious clustering of artifacts, but there was no evidence of different sizes of artifacts being moved more or less than others.

Plaggen soils are considered Ap horizons. These are soils formed through the addition of sod turves and manure as a fertilizing agent. They are most commonly found in Europe, particularly the Netherlands, where sods were left in animals’ stalls to collect dung and were then spread on fields. Plaggen soils can be recognized as overthickened humus-rich A horizons. The excavations at Kalkriese, Germany, which identified a rampart associated with the Battle of the Teutoberg Forest (9 AD) cut through a solid meter of plaggen before encountering archaeological deposits (Rost 2007).

E Horizon

One of the most visually distinctive horizons, E horizons are usually gray in color, in contrast to surrounding strata. They are usually sandy or silty in texture and lack organic matter and compounds of iron and aluminum. They form as the result of massive leaching of clays, organics, and minerals, which leaves behind quartz and other durable materials, resulting in the light color. E horizons are associated with coarse parent material and wet conditions, which pass large amounts of water through the soil, enhancing leaching, and a vegetation community that produces acidic leaf litter. These are most frequently found in forests, particularly coniferous, and heather patches (Holliday 2004, 198, 267). Artifacts are commonly found in E horizons, as Anderton (1999) found for a group of sites from the Upper Peninsula of Michigan, where some sites had more artifacts in the E horizon than other horizons.

B Horizon

The B horizon is where the minerals and clays eluviated (removed) from overlying strata illuviate (collect). The structure of B horizons tends to be more blocky than granular, as was the case with A horizons. They tend to be redder than A and E horizons, which can be nearly white. There are a multitude of subhorizons, reflective of the illuviation of different minerals and organic materials into this horizon. Boundaries between these different horizons, when they are present, can either be abrupt or gradual. The following descriptions are drawn from Birkeland (1999), Vogel (2002), and Holliday (2004) unless otherwise noted.

Bh Horizon

This horizon is where aluminum oxides accumulate along with organic matter eluviated from the A and E horizons. Bh horizons are usually dark brown in color, reflecting the accumulation of materials that leached through the E horizon. They do not contain significant amounts of iron, but are rich in humus (Goldberg and Macphail 2006, 49, 67).

Bs Horizon

This horizon contains significant accumulations of iron or iron and aluminum oxides, yet lacks significant organic content. This zone is where the minerals leached from the E and A horizons accumulate, but where no organic materials have accumulated. It, along with Bh and Bhs horizons (see below), constitutes podzols.

Bhs Horizon

Bhs horizons are similar to Bh horizons, but instead of containing significant aluminum oxides with little iron presence, Bhs horizons contain significant iron and little aluminum. Like Bh horizons, Bhs horizons can be dark brown, red, or coffee-colored and underlie gray/white (albic) E horizons.

Both Bh and Bhs horizons are podzols (also referred to as podsols and spodosols), which form from materials leached out of A and E horizons. They form dark bands just below gray E horizons. They are most common in northern North America, Europe, and Asia, but have been found in isolated pockets in Africa, Australia, Borneo, and Florida.

Bk Horizon

These horizons are accumulations of alkaline compounds, sometimes forming cemented layers, which are typically accumulations of calcium carbonate. These visible accumulations of calcium carbonate frequently manifest as whitish globular concretions.

Bo Horizon

These horizons consist of dense accumulations of iron and aluminum oxides. These accumulations are strong enough to form laterite (red-brown bricklike layers up to several meters thick).

Bo horizons form in tropical areas where high annual rainfall and hot temperatures dominate. Soluble sodium, calcium, silica and magnesium leach out of the soil, leaving behind iron and aluminum, which can either be soft or hardened to the point of being used in construction as cut bricks. Laterite bricks were extensively used in India and formed the basis for the earliest construction stages at Angkor Wat in Cambodia (Uchida et al. 1999). In the United States, laterite deposits often contain minerals rich in a number of metals with important industrial uses. Metals such as nickel and aluminum have been extracted from minerals such as bauxite collected from laterite deposits in the southeastern United States.

Bw Horizon

A Bw horizon manifests a different color (a redder hue or a higher chroma than the underlying C horizon) without an appreciable accumulation of new material. It is essentially a weakly formed B horizon. Visually distinct from the overlying and underlying strata, the Bw horizon has yet to develop characteristics of one of the other subcategories of B horizon. Bw horizons will also be appreciably different in soil structure from the surrounding strata.

Bt Horizon

This is similar to a Bw horizon, but has a noticeably higher presence of illuviated clay particles; hence it is sometimes referred to as an “argillic” B horizon. A Bt will have the same color characteristics as a Bw or a B horizon in general, but its texture will be significantly more clayey (Goldberg and Macphail 2006, 49).

By Horizon

The ‘y’ in this case stands for the presence of elevated levels of gypsum (calcium sulfate). Gypsum forms strata in highly arid areas, regardless of temperature, and forms crystals that are silt or sand-sized. In areas with high quantities of gypsum weathering form parent material, distinct horizons can form in the soil (Toomanian et al. 2001). By horizons are light in color, like an E horizon, but frequently form into dense hardpan layers. They are found primarily in deserts, such as in the American southwest.

Bz Horizon

Salic (salty) soils in the B horizon are referred to as Bz horizons. These are dominated by halite and other nitrogenous salts. These are similar to gypsum-dominated By horizons, but the salts in Bz horizons are much more soluble than in By horizons. Bz horizons form in very arid climates.

C Horizon

This horizon underlies the B horizon, and is essentially the sediment out of which the soils formed and which the pedogenic (soil forming) processes that create B and A horizons have not penetrated. It can be any color, and is likely the color of the original sediment. It will lack all soil structure, being simply the structure of the original sediment. There will be little evidence of animals reaching into this horizon, unlike the overlying strata, for which formation is at least partly due to the action of fauna.

Some advocate the use of a “D” horizon to discriminate between the upper bounds of the C horizon which, though largely unaltered by pedogenic processes, do experience some slight modification, and that part of the original sediment that truly remains without impact from pedogenesis. As of yet, this concept has not been widely employed in geoarchaeology.

R Horizon

The name for the R horizon derives from the term “regolith”, a concatenation of the Greek words rhegos (“blanket”) and lithos (“rock”). It is essentially the original bedrock underlying all sediment and soils.

Universal Modifiers

The codes “b” and “g” can occur in several different master strata. Those horizons that use the “b” modifier have been buried by subsequent sedimentation. The “g” modifier is used to denote gleyed soils. These are soils that are so thoroughly inundated with anaerobic (oxygen-free) water that iron and other chemicals cannot oxidize. Reduction of these substances by bacteria in the soil produces a gray, blue, or green soil deposit. When the water table rises and falls in a region, partial oxidation can occur, leading to soils that in addition to the usual colors associated with gleying can have nodules of red iron oxide present, creating a mottled deposit (Holliday 2004).

Appendix C

IDENTIFYING DISRUPTED STRATIGRAPHY

Whether a site maintains its integrity as a historical or archaeological resource is determined by CRMs and their consultants must determine if a site maintains its integrity as. As it is used here “integrity,” is a technical term that is defined in the *National Register Bulletin No. 15* (National Park Service 1991) and focuses on seven basic elements. It is an important aspect of the CRM process, since a site merits listing on the National Register of Historic Places (NRHP) only if it retains integrity. The NHPA applies only to sites that are or could be listed on the NRHP, so it is only those sites that are determined through the NHPA Section 106 review process[2] to have retained integrity that the Army is legally required to consider when developing an undertaking. Writings by both Hardesty and Little (2009, 60-64) and King (2008, 2009) contain fuller discussions of the integrity concept.

While *National Register Bulletin No. 15* gives guidelines for making integrity determinations, it also recognizes that there is room for some subjectivity regarding the extent to which a site may retain or lack integrity. CRMs should be careful, therefore, to avoid too-rigid applications of the criteria given when rendering determinations regarding integrity and significance.

Archaeological deposits (including features, artifacts, human remains, and floral and faunal remains) occur within or atop soils and sediments. These different deposits relate to each other spatially and temporally, based on the manner and timing of their deposition. The distributions of materials and features across a site are the basis for inferences about chronological, functional, and other associations among cultural deposits. In order to correctly interpret an archaeological site, the archaeologist must be able to recognize when the archaeological deposits have been disturbed, what might have caused the disturbance, and how extensive and damaging that disturbance

[2] Section 106 of the NHPA requires federal agencies to take into account the effects of their undertakings on historic properties, and afford the Advisory Council on Historic Preservation (ACHP) a reasonable opportunity to comment. The historic preservation review process mandated by Section 106 is outlined in regulations issued by ACHP. Revised regulations, "Protection of Historic Properties" (36 CFR Part 800), became effective January 11, 2001.

was. Knowing this will help the archaeologist understand what appears before them in the excavation unit, shovel test pit, or remote sensing data.

The following discussion focuses on how the field archaeologist can interpret stratigraphy as one aspect of the process of evaluating a site’s integrity, significance, and research potential.

Stratigraphic Mixing

The lack of stratigraphy can be taken as clear evidence that either some form of disruption has taken place or the sediment being excavated is newly-deposited, bearing in mind that disturbance does not immediately equate to loss or lack of integrity. The archaeologist will have to make a determination in the field regarding whether or not the level of disturbance is severe enough to destroy a site’s integrity.

A number of different processes can impact strata but leave some level of archaeological information behind. These processes constitute what is known as “pedoturbation” or soil mixing. Pedoturbation comprises a set of sometimes overlapping factors that churn the soil and blur or destroy strata. While this mixing generally is detrimental to the amount and variety of information that a site can yield, field visits will be required to assess the extent of the damage.

Faunalturbation (disruption caused by animals) is a classic example of pedoturbation. Large burrowing animals can destroy features, mix strata, and move artifacts around within a site. There is no reliable pattern of displacement for the artifacts moved, and no size of artifact is more or less prone to being moved (Mello Araujo and Marcelino 2003). Animal burrows that have been filled in with sediment, which can crop up in archaeological excavations, are known as “krotovinas.” Large animal burrows can actually be a source of archaeological information that can be examined without digging. If an animal burrows through a site, artifacts may be thrown out of the mouth of the burrow into a resultant dirt pile. Examining these piles can aid surface surveys.

Smaller animals can produce similar effects. In the southwest, ant mounds dug into sites often include small flakes of turquoise and other small artifacts or artifact fragments that were part of the material removed during the construction of the mound.

Ants, termites, and particularly earthworms can have other effects, however. They move sediments around, can break up features, and eat seeds that would have otherwise yielded important data. This churning can both help to form soil strata, (as was seen above with earthworms digesting organics and depositing them on the surface) as well as disturb it (if densities of earthworms become too great or a new, deeper-burrowing breed moves in).

What smaller fauna cannot do, however, is consume large, durable material such as ceramic shards or stone artifacts. The deepest extent of bioturbation caused by worms and their ilk is known as the “biomantle” and can, in some situations, be recognized as a consistent pavement of stones and artifacts (Holliday 2004). Though once situated in overlying strata, the elements of the biomantle sank as the bioturbators consumed the smallest of the underlying soil materials and re-deposited them on the surface as, in the case of worms, fecal material. This action takes the smaller, digestible soil materials from beneath large objects and moves them upwards, thus causing subsidence of the remaining large objects (Holliday 2004). Though their vertical position has been lost, their horizontal context may remain as a palimpsest that, as Binford (1981) and others (Bailey 2006) have shown, can retain useful archaeological information.

Strata Inversion

Trees have the potential to mix or completely invert strata within a very restricted area. This occurs when a tree falls, pulling up massive amounts of soil with its roots. This soil can then fall back into the hole, upside-down. The size of such a disturbance will be determined by the size of the root ball that the tree took with it when it fell. Any artifacts that were displaced along with the dirt adhering to the roots will be re-deposited out of its original archaeological context. Wood and Johnson (1978, 330) note that, though this may seem like an isolated possibility, over time many (if not most) trees within a given region could go through this process. In an unpublished study reported by Wood and Johnson (1978, 330), meteorologist Jack Linde estimated that, over the period of 1,000 years, every square inch of the State of Illinois will be directly impacted by a tornado bringing winds that could uproot any tree. The potential for widespread disturbance to soils (particularly in forested areas) is, therefore, a possibility.

Trees can also leave behind root casts. These occur after a tree dies and the roots rot away. The space the roots once occupied fills with sediment and forms an archaeologically recognizable feature within the soil. These can appear to be quite similar to krotovinas. Note that, for a recognizable root cast to form, the in-filling sediment has to be a different color from the soil in which the root decayed. If it is not, the root cast may not be visible to the naked eye. Also, if the root rots away and the space it occupied collapses quickly, before it can be filled with other material, no root cast may form. Waters (1992, 309) points out that, when a root rots away and the cavity it leaves behind collapses, artifacts situated near that root may be displaced downwards. Conversely, a living, growing root may press nearby artifacts upwards as it takes up increasing space in the surrounding soil. These movements, though identifiable, are not likely to be significant. Some root casts could be mistaken for post holes or other archaeological features.

Soil Cracking

Various processes can crack open soils, allowing materials from upper strata and the surface to infiltrate lower levels, filling them with sediment. Cryoturbation (cold mixing) can cause soil to freeze and contract, forming crevasses infilled with ice or sand. Such cracks can grow to 10 m in width and 50 m in depth in very cold climates. Ice wedging is most frequently encountered in Alaska and northern Canada, though ice wedge casts related to the colder climates of the Pleistocene have been documented in the lower 48 states. Horberg (1949) identified a small ice wedge cast that was in-filled with sand in Bureau County, Illinois, outside of Chicago. Ice wedge casts appear wedge-shaped in cross-section, with the point downward. They occur most frequently in soils that are frozen for only a portion of the year.

Argilliturbation (clay mixing) occurs in soils with very high clay content. Some clays hold water well, and when saturated, swell in size. Shedding water can cause the soil to contract and crack. Seismiturbation is churning related to earthquakes, which can cause the earth to crack catastrophically. The Mississippi Delta area is full of seismiturbated areas, indicated by “sand blows,” places where the soil flexed then broke, blowing sandy soil out and creating an archaeologically-recognizable feature (Figure C-1). Many sand blows in the Midwest relate to the great New Madrid earthquakes of 1811 and 1812, which measured 8.1 to 8.3 on the moment magnitude scale, strong enough to ring church bells in New York City from the quakes’ epicenter south of St. Louis.

Some sites may literally be split in two, with the parts displaced laterally if they occur over an active fault. This is true for strike-slip faults, where two plates are moving past each other. In normal faults and thrust faults, the strata of the hanging wall of the fault will be exposed while the strata of the footwall will be buried (Noller 2001, 153-154).

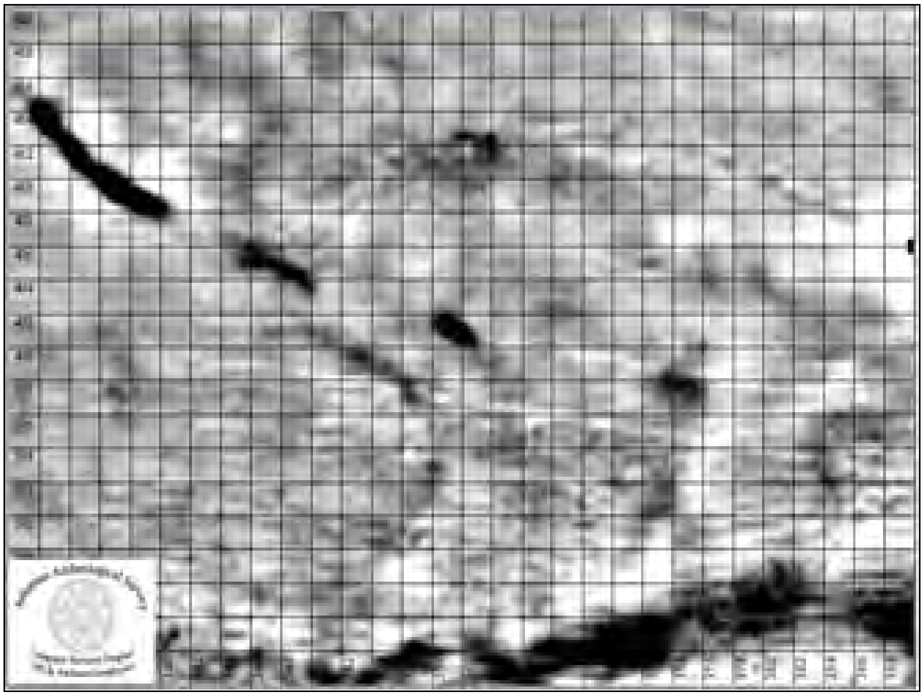

Figure C-1. Electrical resistance for a prehistoric site in the New Madrid Seismic Zone (dark linear features are sand blows). (Courtesy Dr. Jami Lockhart, Arkansas Archeological Survey)

Cracking can also occur through a process known as crystalturbation, where repeated formation and dissolution of salts in desert climates causes expansion and contraction that can produce cracked surfaces much like those formed by frost action (Wood and Johnson 1978, 362)

All of these processes can redistribute archaeological material within the soil column. Most frequently, this involves artifacts from upper strata falling into the cracks and thus being redeposited in lower, older contexts. With argilliturbation, materials may actually be moved upwards, as the swelling and contraction of clayey soils has a tendency to push large materials upwards, eventually depositing them on the surface.

Argilliturbation and seismiturbation are more likely to create lateral cracks, whereas cryoturbation and crystalturbation can cause patterned cracks in the ground resembling a paved walk or brick path. The latter two are much more continuous and patterned than the former. The polygonal cracking associated with cryoturbation and crystalturbation can be very large.

Solifluction

In areas with a history of glacial action, permafrost, or near-permafrost conditions, the joined processes of solifluction and gelifluction pose a danger to the archaeological record. Solifluction simply means the movement of waterlogged soil downslope as it is pulled on by gravitational forces. This differs from the colluvium process in a number of ways. Colluvium is the downward movement of loose soil particles. Gravity is the active agent in both cases, but with solifluction, entire soils move as a distinct mass, not in particulate form as is the case with colluvium. The high water content of the soil is the active agent in solifluction, whereas colluvial deposits are defined as those only acted upon by gravity. Colluvium does not produce the lobes that can occur with solifluction (Figure C-2).

Gelifluction is a kind of solifluction that occurs in areas with permafrost or near-permafrost conditions. During the summer, only the upper soil strata thaw. Water from the thaw and any additions through rain or runoff cannot penetrate the still-frozen layers that lie below. As a result, the thawed soil retains the moisture and becomes steadily less viscous.

Visual indicators of gelifluction include obvious wavelike undulations on the surface of a hillslope, caused by the plasmatic movement of soil downslope. Stratigraphically, a geliflucted landscape will have a markedly wavelike horizon barrier unlike the more common straight-line barrier. As the upper strata flow downhill, they can fold over on themselves, creating jumbled, sometimes inverted, stratigraphy. Artifacts can also be scattered from their original context. Hopkins and Giddings (1953 [cited in Waters 1992, 302-303]) encountered this at the Iyatayet site on Cape Denbigh in Alaska. Gelifluction literally inverted the stratigraphy of part of this 10,000 year old site. The site’s stratigraphy was salvageable, though, because part of it remained in the permafrost, meaning it had not been subject to gelifluction and thus was intact.

Solifluction, gelifluction, and blocksliding (landslides) cover pre-existing surfaces that, at the time of burial, are undergoing pedogenesis, and can therefore place older archaeological materials over younger ones, thus inverting conventional temporal associations between depth and age.

Figure C-2. Solifluction lobes in tundra. (Source: U.S. Department of Interior)

Similar to solifluction and gelifluction, mudslides can be fast-moving, destructive, and deposit large amounts of material very quickly. The eruption of Nevado del Ruiz in 1985 buried alive 23,000 people in Armero, Colombia. The eruption of Mount Rainier in Washington 5,600 years ago covered 130 mi^2 of White River Canyon with mud up to 140 m deep. Both of these events were associated with volcanic activity. Volcanic mudslides are known as “lahars.” Common mudslides can have similar effects. The Ozette Site in Washington was covered with a mudslide around 1700 AD (Samuels 1991-1994). When excavated in the 1970s, the rapid burial of the site had promoted preservation of thousands of wooden, bone, and shell artifacts; rare finds for the area.

Cratering (Bombturbation)

Archaeologists working on military installations or battle fields may encounter what Hupy and Schaetzl (2006) recently termed “bombturbation,” the cratering and mixing of soils by explosive munitions during combat or live-fire training. Cratered combat landscapes occur only within the past 150 years, during which time the development of highly explosive ammunition, aerial bombs, and landmines revolutionized warfare.

Bombturbation most frequently results in the complete removal of all soil to form a crater, the rim of which will be crowned with a thin layer of debris from the strata that were just destroyed. Three kinds of craters exist. Type A craters have shallow, clean-swept walls with little to no backfilling from exploded debris. These are associated with explosions on or near the ground (just below or just above). All debris is thrown clear of the crater. These craters are formed by either artillery shells fitted with proximity fuses or aerial munitions designed to explode at or just above the surface (e.g., the BLU-82 “Daisy Cutter”).

Type B craters have walls with around a 45-degree slope and are partially backfilled by the debris that was displaced upon detonation of the explosive. These craters result from munitions that exploded when they impacted the ground or bore into it before explosion. Conventional artillery shells fitted with percussion fuses and similarly fused aerial bombs form such craters.

Type C craters result from munitions that were buried before explosion and create steep-sided craters that are extensively filled by displaced debris (the force of the explosion blows up more than out, so the displaced material falls back into the crater). In-situ munitions such as landmines produce such craters.

Fuller descriptions of crater types and their associations with different kinds of weaponry may be found in the U.S. Army Field Manual (FM) 9-16, “Explosive Ordnance Reconnaissance” (United States Army 1981 [cited in Hupy and Schaetzl 2006]). Though superseded by FM 21-16, the latter document does not contain cratering information documented in FM 9-16. Recognizing different types of craters can indicate where archaeological materials displaced by explosion would be redeposited. Type A craters will be more likely to be ringed with an apron of displaced material than are Type C, which will likely be largely backfilled after the explosion by the displaced material falling back into the crater.

The documented pedoturbation associated with bombturbation focuses primarily of the physical removal of soil strata by explosion. No known publication has explored the effect of the vibrations associated with explosion on archaeological strata.

While this kind of pedoturbation may be marked and intensely damaging to the soil and any site that lies in proximity to it, bear in mind that the crater itself, under certain conditions, could be taken to be a historical property worthy of preservation in and of itself. The battle-scarred landscape of Point du Hoc, France, has been maintained as a memorial to the men who fought there in the Second World War. Bombturbated landscapes are most heavily associated with western and central Europe (World War I and II) and Southeast Asia (Vietnam War). Working in a bombturbated landscape should always give the archaeologist reason to be aware of the possible presence of unexploded ordnance, regardless of the amount of time that has passed since the conflict or the thoroughness with which the area has been cleared. World War I munitions continue to kill French farmers on the Western Front.

Anthropogenic Disturbance

People also do significant damage to site integrity. Outside of the construction activities that generate much of the business for archaeologists in the United States, there are two distinct practices that can produce dramatic, usually negative, changes in the archaeological record.

Looting

Unauthorized and undocumented digging, sometimes referred to as looting, can, if sufficiently intensive, greatly degrade or destroy the integrity of a site. The most obvious evidence of looting taking place at a site is the presence of numerous, randomly excavated pits, trenches, or holes. These can range in size from the equivalent of a shovel test pit to a deep, backhoe-dug hole. If recently dug, they will still appear as a hole, often with a small pile of excavated dirt nearby. Holes may sometimes have sod re-placed over them, but they are still visible as excavation holes. These will likely still appear as a depression, area of dead grass, etc. Looters have even been known to visit archaeological sites after archaeologists have completed work and gone through the discarded soil and broken open filled-in units to see if anything was missed. Archaeologists encountering a looted site, even if there is no surface evidence for looting, will likely encounter the jumbled, inverted, or homogenized strata that result from the digging and backfilling of looter holes and trenches. The erratic nature of many looter holes and lack of documentation for their presence at a given site will differentiate them from pre-existing archaeological excavation pits.

Less obvious, but particularly common where metal detector operators have been operating, are the presence of discarded excavated materials. If working on a battlefield, fort, or other location where a metal detector operator would be looking for military or other material, it is common to find modern cans, foil, and civilian metal items discarded in discrete areas around the area that was looted. Sometimes these discards will be thrown at the base of a tree or actually hung from its branches. This is done to keep metallic items away from areas the diggers might want to revisit. Placing them where they will not be passed over again by the metal detector cuts down on the erroneous hits that the operator will encounter during a repeat visit. Extensive metal detector looting in the past can disrupt the stratigraphy of a site in much the same way that more traditional looting does.

Sites that have been looted over a long period of time will sometimes have trash piles if the looters camped at the site. Bottles, food containers, cigarettes, batteries from flashlights (if working at night), and many other items have all been found in the vicinity of looted sites. This is circumstantial evidence for anthropogenic disturbance that can, if sufficiently extensive, make a site ineligible for listing on the NRHP.

Land Leveling

Land leveling is perhaps the most disruptive of the various land-use behaviors common to the United States. Intended as an aid to irrigation, land leveling involves selecting a desired elevation for an existing field, then, using heavy equipment to remove soils from high points and fill in low areas, creating as close to a flat surface as possible. This practice strips away some sites, mixes others, and buries the remainder beneath fill that potentially contains cultural materials from different contexts. McGimsey and Davis (1968) estimated that 25% of the known archaeological sites in the Arkansas portion of the Lower Mississippi Alluvial Valley were completely destroyed by land-leveling between 1958 and 1968. When a landowner in Chicot County, Arkansas, tried to level his own land, he discovered a a large village complex comprising 66 mounds that would have been lost had a professional land leveler been brought in (McGimsey and Davis 1968, 30).

Leveled lands will, not surprisingly, appear much flatter than would be considered natural for the local topography. This is not to say that all predominantly flat terrain has been leveled, as some areas along the Gulf Coast and the Midwest are remarkably flat by dint of their geologic history. However, in areas of high agricultural activity and where soil strata appear mixed, cut-off, or non-existent, exceedingly flat lands may have been subject to leveling. That the first areas targeted for land leveling were frequently natural river levees in alluvial planes, precisely the preferred locus for archaeological sites, makes this an extremely disruptive practice. Asking landowners or land managers whether or not an area has been leveled will probably yield a useful answer, as most land leveling has taken place within recent memory.

Given the significant disruption that land leveling imparts, and the massive areal extent that it entails, there have been few attempts to recover archaeological information from leveled deposits. Unlike plowing, which leaves the soil/sediment intact, land leveling completely displaces it and all associated materials, rendering all contained archaeological materials of little value, particularly from a spatial standpoint. It is possible that sites buried deep enough to miss the land leveler’s chisel may remain intact.

Appendix D

COLOR VERSUS TEXTURE CRITERIA FOR DETERMINING SOIL HORIZONS

Identifying horizons and their subdivisions within a soil profile requires the ability to recognize differences in soil properties within the soil column. These differences occur within a suite of soil characteristics that include color, texture, organic matter, structure, pH, and a few other factors. The most precise evaluation of soil characteristics must take place in a laboratory setting, but assessments and descriptions can be made in the field that are adequate for most archaeological purposes. In field classifications, color and texture are the most frequently used criteria for horizon designations. Though color is the most readily recognizable characteristic, texture may be less prone to the subjectivity of the excavator’s assessment when it comes to identifying separate layers (Birkeland 1999). Using both factors in tandem is standard practice for identifying soil horizons in the field.

Color

Color is not a stable property of a soil horizon over long periods of time. As leaching and eluviation from one layer to others proceeds, soil color will change. It changes from the initially deposited sediment to when soils form within that sediment (Waters 1992, 43). As soils form and as chemicals translocate within the emerging soil strata, the colors will shift. Over time, an individual soil’s color may gradually shift from yellow to brown to red, reflecting a change in the chemical makeup of that soil.

Documenting soil color requires the use of a standardized system for describing different colors. This permits not only the communication of colors between two people, who may apply distinct labels to the same color, but also globally, which obviates the problem of international variation in the way color is understood and conceptualized. It also buttresses soil descriptions against changes in color terminology that take place within a single community over time (Kay 1975). The Munsell system is very widely used as a means of standardizing descriptions of soil color.

The Munsell system is named for artist and Professor Albert Munsell, who developed a system of color terminology because he disliked the traditional practice of using names for colors, finding the terms too subjective. Munsell’s (1905) system used letters and numbers to describe color. Refined in 1929, Munsell’s system remains in wide use in the social and earth sciences. The Munsell system consists of three parts, an alphanumeric hue, followed by a value code, and ending with a chroma indicator.

Hue refers to the contributing colors (red, yellow, green, blue, and neutral). Chroma is the degree of departure from gray that the color expresses. Value is the lightness of that color (high values are lighter than dark soils with low numbers). An example of a color description is 2.5YR 4/2, corresponding to the color chip on the 2.5YR page in the Munsell book with a value of 4 and a chroma of 2. These measurements should be noted as frequently as is necessary to accurately describe the soil profile in the field notes for a project.

Variation in soil color can be used as one means to discriminate among different soil horizons. Color provides a relatively straightforward way of identifying gross differences among different soils. As is the case with most aspects of fieldwork, greater experience breeds increased ability to pick out subtle variations in the color of different strata. Reading a soil profile becomes easier with experience; however, there are a few suggestions for analyzing soil color that should be kept in mind.

First, always keep a spray misting bottle of water available, as the colors will bleach out of a soil profile as the soil dries. Dry soils are harder to read; the variations in color become less pronounced as moisture content drops. Soil dryness also increases the likelihood that smaller differences between two strata will not be noticed, leading to the recording of a less specific soil profile. Periodically moistening the face of the soil profile will allow for recognition of finer differences. Ensure that the sample has been moistened but is not saturated. This will enhance variations in color, allowing a soil sample to be accurately matched to one of the chips in the Munsell book (Figure D-1). Some archaeologists feel it appropriate to take two measurements, one with wet soil, and the other with dry. Generally, the moistened sample is adequate. Record the measurement in the Munsell system of hue, value, and chroma (e.g., 10YR 4/3). Descriptions of soil color should specify whether the soil was moist or dry. A different measurement should be recorded for each horizon within the soil profile (Banning 2000, 241). Multiple colors can be used to describe heterogeneous strata (e.g., a horizon that includes mottles of a second color).

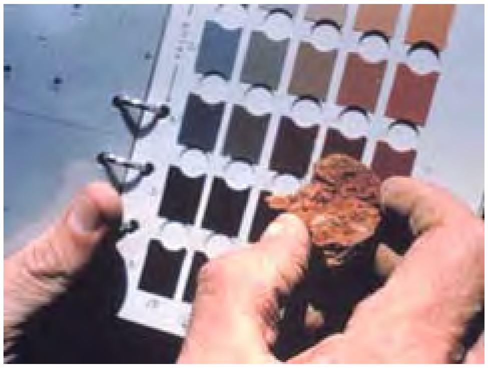

Figure D-1. Determining soil color by using a Munsell Book. (Source: U.S. Department of Agriculture.)

Categorizing soil color should be done in natural light, although direct sunlight will make it more difficult to detect subtle variation. It is best to take Munsell readings in shade.

Color can help identify soils that contain either oxidized or reduced iron particles. Soils that have significant red, yellow, or brown tones contain oxidized (ferric) iron, whereas those that contain reduced (ferrous) iron are gray, green, or black in color (Cornwall 1958). Reducing environments are starved of oxygen, as opposed to oxidizing environments, which contain oxygen and therefore permit the oxidization of the iron particles in the soil.

Soil color can thus be used as an indicator of the rapidity with which the soil drains water. Uniform-colored soils exhibiting the traits of oxidation are well-drained, while mottled soils indicate a soil that undergoes repeated cycles of high and low water saturation. A uniformly gray, greenish-gray, or bluish layer indicates that it has a reduced (oxygen-starved) environment. These gray layers are usually denoted as “g” horizons, a reference to the occurrence of gleying, which is the conversion of iron into a reduced state as a result of oxygen starvation (Waters 1992, 48). In the absence of oxygen, bacteria become the agent of change. Gleyed soils can be the result either of local characteristics that do not permit water to drain from the soil, or a perched water table, where an impermeable stratum undergirds the gleyed layer, preventing the movement of water downwards into better-drained strata. Gleying typically takes place where there is essentially no drainage gradient and there is no passage of water through the soil

(Cornwall 1958, 88). The mottling associated with a partially drained soil usually occurs at the top of a gleyed soil, as a lowered water table allows for at least partial re-oxidation of the iron compounds in the soil. However, if a perched water table overlies well-drained sediment, such as sand with few organic compounds, the lowest reaches of the gleyed soil may come into contact with oxygenated water, causing mottling to occur at the bottom of the gleyed soil instead of the top (Cornwall 1958, 88).

Finally, certain layers within most soil profiles are identified with certain colors. An E horizon, for instance, usually appears gray or whitish in color. E horizons usually appear between A and B horizons and owe their color to being heavily leached of most nutrients, leaving behind a layer composed primarily of quartz. A horizons usually appear darker than the layers below them as they are largely composed of decaying organic matter that is in the process of being leached into lower levels. The more decaying organics in a soil, the darker brown in color it appears. In some cases, extensive leaching can lighten an A horizon, giving it a lighter brown to gray color (Vogel 2002). Generally, reddish soils contain a significant amount of ferric (oxidizing or “rusting”) iron.

It is important to note that the texture and structure of a soil can affect the way that it shows color. Generally, the intensity of a soil’s color will be directly proportional to how much of that coloring element is present in the soil. A deep red soil, for instance, will likely have high iron content. However, soils with large particles may appear darker and more intense than soils with similar chemical compositions but with smaller particles. As a particle’s surface area relative to its volume increases, it requires a greater quantity of any given coloring agent to make the particle appear to have the same color as a larger particle with proportionally less of that element. For instance, a clay and a sand with the same iron content will appear to be two different colors, the clay being lighter. To exhibit the same color, the sand would have to be paired with a clay having a higher iron content (Birkeland 1999, 9).

Texture

Though not as immediately discernable as color, a soil’s texture is a better indicator of archaeologically meaningful differences in soil. Soil texture descriptions look specifically at the material that is less than 2 mm in diameter, thus eliminating sticks, rocks, leaf litter, and any other material that one may encounter in an excavation (Birkeland 1999, 10). It requires a measure of sensitivity and a good deal of practice to become familiar and comfortable with describing soil texture. Working with soil texture can allow differentiation between two soils that are similar in color but not in structure, adding greater specificity to a soil profile and, ultimately, providing greater detail that may prove useful in developing a fulsome interpretation of an archaeological site.

A soil’s texture depends upon the relative abundance of three constituents: clay, silt, and sand. These three are differentiated by size. Clay is the finest of the three, and represents all materials with a diameter of less than 0.002 mm. Silt is slightly larger, covering materials with a diameter ranging between 0.002–0.05 mm. Sand particles are those greater than 0.05 mm yet smaller than 2.0 mm. The relative proportions of each are first assessed, and then the diagram shown in Figure D-2 is used to determine the appropriate texture for that soil. It is clear from the diagram that soils with high clay contents will almost invariably be referred to as clays, whereas silt and sand must overwhelm a soil type for it to be named purely a silt or a sand. Anything termed a loam has relatively even mixtures of at least two of these components.

Sand differs from silt and clay in that it is divisible into finer classifications. This is a convention established by the U.S. Geological Survey and used specifically in the United States. Sands are divisible into very fine sands (0.05-0.1 mm), fine sands (0.1–0.25 mm), medium sands (0.25–0.5 mm), coarse sands (0.5-1.0 mm), and very coarse sands (1.0–2.0 mm). As with the distinctions between clay, silt, and sand, separating these different gradations requires a degree of familiarity with the material that takes time to develop.

The following flow chart (Figure D-2) can walk the beginner (or even the seasoned soils veteran) through the process of determining the constitution of a given soil sample. Vogel (2002) recommends acquiring samples of pre-classified soils that the novice can practice with to develop a familiarity with the different gradations of particle size. There is no substitute for repeated handling of different soil types to permit quick and accurate field identifications.

The best means for classifying soils are found in the laboratory, where a battery of tests may render the most accurate interpretation of how to classify a soil. However, this does not mean that field assessments lack value. Frequently, field assessments are the only observations recorded for a soil, as few archaeological firms spend the time and resources to conduct analyses of the soil matrix that match in intensity and precision those analyses conducted for artifacts. Having some understanding of the soil characteristics based on a rough field assessment is better than having none at all. Vogel (2002) offers the general rule that sand will always feel gritty when wet, whereas clay and silt will feel somewhat slimy. Only silt will have noticeable grit when rubbed gently against the front teeth.

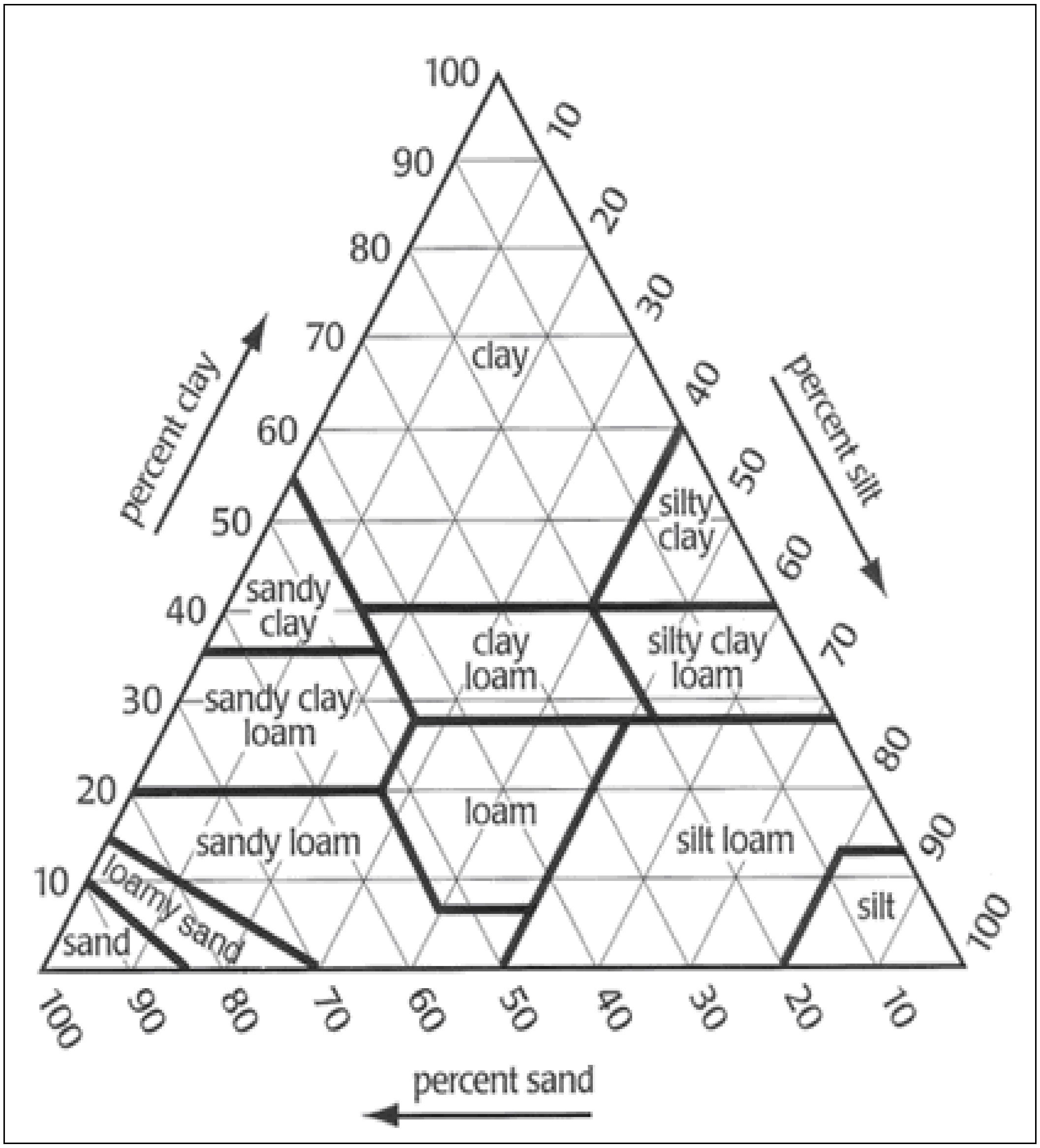

Figure D-2. The textural triangle.
(Source: National Aeronautics and Space Administration.)

It is important to note that a soil horizon need not have completely uniform texture. Sharp discontinuities in texture may represent breaks between strata, but a single stratum may exhibit a gradation of characteristics. For instance, a single stratum may be a silt loam but be slightly sandier at its base than at its top. Such gradations should be recorded in field notes. The textural description system shown above can be used for sediments as well as soils.

The differences in particle size relate to variation in four factors. First, the parent material from which a soil or sediment forms can itself release larger or smaller particles during the weathering process. Once those particles have been dispersed and deposited, they can be weathered in place, usually through mechanical (as opposed to chemical) processes. Over time, a third process can change the texture of a soil, as new particles of different size, such as clay or silt blown or washed into an area, may be deposited and introduced into the soil horizon. Finally, a process known as “neoformation” (literally new formation) may take place. This is where new soil particles precipitate out of the chemicals present in the moisture surrounding pre-existing soil particles (Birkeland 1999, 10).

Further material on color and texture can be found in Birkeland (1999), Holliday (2004), and Waters (1992), to name a few. In addition to differentiating strata, both texture and color can be used to make other archaeologically relevant observations. Color reflects the amount of organic material and the kinds of minerals the sediment in which the soil formed was comprised of, as well as (roughly) the soil’s iron content. It also indicates when and how extensively a soil has been waterlogged (using gleying and mottling). Texture can be used to identify when soil and sedimentary layers have been eroded away and then covered by new deposition. Figure D-3 can assist in identifying soil types by texture.

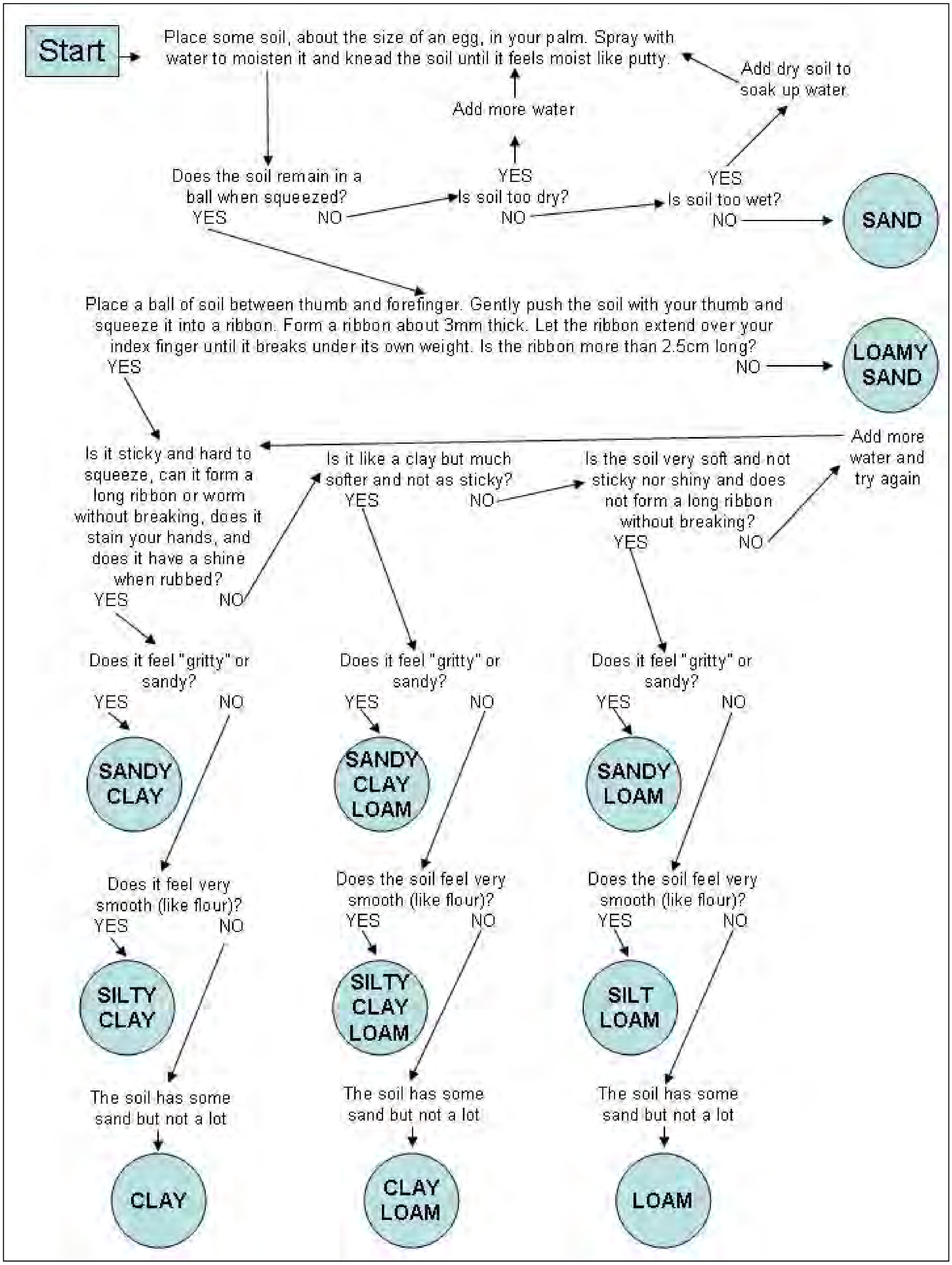

Figure D-3. Flow-chart for determining soil texture. (Adapted from National Aeronautics and Space Administration.)

Appendix E

GEOCHEMICAL INTERPRETATION IN ARCHAEOLOGY

Not all soil analyses are based on physical properties observable in the field. A number of chemical examinations of soils and sediments can enhance our understanding of the way people used and altered soils in the past, but these require careful sample collection and preparation. In many cases, specialized laboratory equipment is required to analyze the samples. This appendix is a brief overview of common tests using different chemicals. Each test, however, has limitations.

One problem common to many of the chemical tests, as discussed below, is the potential for an observed chemical property to be the result of multiple processes (equifinality). It is easy to demonstrate that a reaction is the result of a certain process, but it is much more difficult to demonstrate that it is the result of ONLY that process. The archaeologists who developed these tests have all contended with equifinality at some point in their research. Discussed below are among the most reliable associations between human behavior and extant chemical signatures of that behavior.

The following analytical methods add to our understanding of the chemical makeup of soils and human impact upon them. They add information about many aspects of past environments and can help reconstruct the internal spatial structuring of archaeological sites. Adding these chemical data to other forms of archaeological information (artifacts, documents, etc.) betters our understanding of the past.

Carbon

In archaeology, carbon analysis is most frequently (but not only) applied as C-14 dating. While carbon dating is used to establish the antiquity of organic materials and their containing features, other analyses can identify the florae present at the site in a particular point in the past, and that can help tell us about climate fluctuations over time as well as the intensity and duration of human occupation (see Cook and Heizer 1965 as mentioned in regard to calcium, below).

Humans contribute to the formation of soil organic matter (SOM), which is rich in a number of chemicals (C, N, P, S) and humus (degraded organic material). SOM from habitation sites is much richer (2-2.5 times) in carbon than are soils from areas that have no appreciable history of human habitation (Holliday 2004). SOM analysis involves the systematic collection of soil samples from a potential site, much like a shovel test survey. These samples are then sifted to remove non-soil materials (stones, roots) and then air-dried. The remaining matrix is burned in a controlled-temperature furnace for a set period of time. Comparing the mass of the post-burn sample with that of the pre-burn sample tells the archaeologist what percentage of the sample mass was carbon.

Werts and Jahren (2007) have begun probing a link between carbon levels in soils taken from the proximity of hearths and the temperature of the fire to which they were exposed. They have, to date, identified a strong link between the loss of organic carbon and moderate cooking temperatures (200-400 °C, a temperature high enough to boil water but not burn wood) and thus an appropriate cooking temperature. They envision developing their analysis to allow identification of cooking hearths as opposed to fire pits used in other purposes.

Other archaeologists (e.g., Nordt 2001) have done work on carbon levels present in soils as a means of reconstructing ancient climates. This process only works in areas with successions of Carbon 3 (C_3) and Carbon 4 (C_4) plants (those that photosynthetically convert carbon dioxide from the air into 3 or 4 carbon compounds, respectively). C_3 plants are most prevalent in deserts and other arid environments, while C_4 plants dominate wetter temperate or tropical grasslands. Where applicable, this method helps establish the expansion and contraction of different plant communities over time, which in turn leads to greater knowledge of environmental change in the past.

The basic mechanism behind carbon analysis involves measuring carbon isotopes. Three of these isotopes exist in SOM, ^{12}C, ^{13}C, and ^{14}C. Of these, ^{14}C is unstable and breaks down at a constant rate, thereby allowing isotopic dating. Of the other isotopes, ^{13}C is used in carbon fractionation analysis. Although ^{13}C exists in the atmosphere, it is discriminated against during photosynthesis by different plant groups. C_3 plants typically contain -27‰ (parts per thousand) relative to atmospheric ^{13}C levels. C_4 plants discriminate less, averaging -13‰. The ^{13}C content of plants does not break down, meaning that as they decompose and become part of the O and then A horizon, the ^{13}C levels remain the same, and can be measured. The ^{13}C level of a soil sample will, therefore, depend on the proportion of C_3 to C_4 plants that lived at the location where the sample was collected. A uniform C_3 plant population would give the soil a

^{13}C level very close to -27‰. Changes within a soil column indicate changes in the plant community (Nordt 2001).

This kind of analysis is most useful in developing an explanatory model for changes in land and resource use. Changes in settlement pattern, dietary practices, or material culture may be related to changes in climate. To build an argument linking climatic variation and, for instance, changing settlement patterns, there must be a demonstrable shift in climatic conditions. Analyzing carbon ratios in soil is one approach archaeologists may use.

Carbon-13 levels in soils were used at Fort Bliss, Texas, to reconstruct environmental shifts for the past 10,000 years of human history on the installation (Cole and Monger 1994; Monger 1995). A downward shift in ^{13}C indicated a reduction of grassland acreage and an upswing in shrubland approximately 8,000 years ago. Since C_3 plants discriminate strongly against ^{13}C, a downward shift indicates an expansion of C_3 plant communities. These plants thrive in arid conditions, implying a shift to more desertlike conditions at that time.

Carbon SOM analysis requires sampling different levels within the soil column. At minimum, each sample must be 500 mg. If there are significant carbonate inclusions, larger samples are needed as preparation removes carbonate. Avoid sampling root casts and other intrusive material, as these introduce other sources of carbon. In the laboratory, the samples are washed with hydrochloric acid (HCl), then run through a mass spectrometer, which reads the amount of ^{13}C in comparison to a baseline sample (Pee Dee belemnite [PDB] limestone has been chosen as the standard for ^{13}C concentration. PDB limestone has a ^{13}C value of 0‰).

Nordt (2001) contains a more complete description of this process and a more thorough treatment of the chemistry involved.

Calcium

Discard areas (middens) are frequently the sites of disposal for bone and ash, two materials composed significantly of calcium. Over time, the calcium from these discards becomes part of the soil matrix and can be measured. Carr (1982) suggested that elevated calcium levels within a site indicate the location of the garbage area, and that areas kept clean of such debris would have proportionately lower calcium content. Systematic sampling of a site should, therefore, reveal certain areas markedly higher in calcium content. Those areas may then be interpreted as being discard areas that were once (if not still) full of bone and ash.

For example, Sullivan and Kealhofer (2004) used such a calcium survey at Rich Neck Plantation on the Virginia Peninsula to locate concentrations of marl and shellfish remains. Marl is a form of calcium-rich sediment that may form from decayed shellfish. It is known locally as the “Yorktown Formation,” and continues to be mined for fossils and ornamental walkway covering. The area around the Rich Neck kitchen was found to be rich in calcium, probably as a result of the disposal of ash from the hearth, bulk processing of local shellfish, and the use of marl as paving material to keep the activity areas well-drained and clean.

The seminal archaeo-chemical study of soil by Cook and Heizer (1965) found that carbon, calcium, and nitrogen were all found in higher proportions at the centers rather than the peripheries of sites, where occupation would have been less intense. This suggests that there is a general correlation between intense occupation and high calcium levels.

Phosphorous

The most frequently employed chemical tool for archaeological research has been phosphate analysis. Phosphorous can be found in burials, feces/manure, and trash containing animal bone and flesh as well as decomposed plants used by both humans and the animals humans once kept as stock and pets. Unlike other chemicals, phosphorous does not break down readily, and it is relatively resistant to leaching, meaning it stays near the surface and is readily recoverable.

At least some phosphorous is present in most soils. Human occupation simply adds to what is naturally present. Analysis can isolate anthropogenic phosphorous. Cook and Heizer (1965) was the first significant publication in this area of research, though archaeologists have been aware of it as a tool since the 1930s (Arrhenius 1934).

Phosphorous studies generally accomplish two different goals: (1) locating the boundaries of sites and (2) identifying internal activity divisions within sites. To accomplish these goals usually involves gridding a large area where cultural materials have been found, taking soil samples at regular intervals within a definite grid, and then testing the samples for phosphorous levels.

By sampling a large area and performing regular tests for phosphorous, archaeologists can map relative abundance of phosphorous. Those areas subject to human (and animal) occupation will have higher phosphorous levels than areas surrounding them. Creating a distribution map for phosphorous will indicate where the most intensive habitation occurred within the grid, thus delineating the site.

Within the site, different areas will have different concentrations of phosphorous. Stables and other areas where phosphate-rich materials like garbage and feces were discarded will be richer in phosphorous than areas that were kept cleaner. Arriving at this level of discrimination, however, requires a finer sampling of the site than simply establishing its boundaries (Holliday 2004).

In a number of instances, phosphate analyses have suggested places where bodies decomposed following a battle. For instance, archaeologists used phosphate analysis when they conducted research at the possible location for the Roman defeat at the hands of Germanic tribes in the Teutoberg Forest (9AD) near Kalkriese, Germany. Points that were markedly higher in phosphate quantity than surrounding areas within the sample area were interpreted as places where bodies lay after the battle. In the years between the battle and the collection and burial of their bones, the bodies decomposed and added their phosphates to the soil. Since phosphorous does not decompose the way other chemicals do, the potential body locations were still identifiable two millennia after the battle ended (Wilbers-Rost 2007).

Holliday (2004, Appendix B) contains a more complete discussion of phosphorous sampling and analysis in geoarchaeology.

Nitrogen

Like phosphorous and calcium, human occupation also deposits substantial amounts of nitrogen (Rapp and Hill 2006, 122). Unfortunately, nitrogen analysis (like calcium analysis) has not become a staple of archaeo-chemical analyses as have phosphorous studies. There is scant literature available for either calcium or nitrogen analysis. Holliday (2004, 300-301) notes that nitrogen volatilizes relatively quickly (unlike phosphorous), and may therefore be of little use on sites of great age.

As mentioned above, Cook and Heizer (1965) found that nitrogen levels appear to correlate to frequency and intensity of human occupation. In testing sites for nitrogen content, they found that the centers of sites had much higher levels than the peripheries of sites. Supposing that people spent more time near the center of the sites than on its outskirts, the conclusion can be made that humans, through the deposition of waste products of various kinds, increase local nitrogen levels in soil.

Future Directions

As Holliday (2004) writes, recent developments in mass spectrometry facilitate the sampling of more elements along the lines that phosphorous, nitrogen, carbon, and calcium have been analyzed for the past half century. As it is yet a young area of research, there is not a substantial amount of literature on this work yet. Initial studies, however, suggest that elements such as copper, manganese, and zinc are higher in anthrosols (soils with extensive human impact) than other soil types.

Appendix F

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Appendix G

ABBREVIATIONS AND GLOSSARY

Abbreviations

AR	Army Regulation
CERL	Construction Engineering Research Laboratory
CLORPT	Climate, organisms, relief/landscape, parent material, and time (formula)
CRM	Cultural Resources Manager
ERDC	Engineer Research and Development Center
HQUSACE	Headquarters, U.S. Army Corps of Engineers
NHPA	National Historic Preservation Act
NRHP	National Register of Historic Places
PDF	portable document format
POC	point of contact
PWTB	Public Works Technical Bulletin
SOM	Soil organic matter
URL	universal resource locator
WBDG	Whole Building Design GUide
WWW	World Wide Web

Glossary

Albic – Light colored (from Latin *albus*, meaning “white”).

Anthrosols – Soil formed or heavily-modified by long-term human occupation.

Argillic – Of or pertaining to clay or clay minerals.

Argilliturbation – Mixing of soil strata by expansion and contraction of clays contained in the soil.

Beringia – Area between Russia and Alaska that was once a bridge for the movement of people into North America from Asia.

Biota – Total collection of organisms in a geographic region.

Bioturbation – Mixing of soil strata by plants and animals.

Bombturbation – Mixing of soil strata by man-made explosives.

Calcic - Of or pertaining to calcium.

Chroma – Aspect of color in the Munsell system by which a sample appears to differ from a gray of the same intensity.

Chronosequence – A sequence of related soils that differ in their degree of profile development due to temporal variation.

Colluvium – Material deposited downslope by gravity.

Cratering – The formation of craters.

Crystalturbation – Mixing of soil strata by the growth and decay of crystals.

Clovis – The earliest well-known culture in the New World. Dating to around 12,000 years ago, Clovis material is found throughout North America.

Cryoturbation – Mixing of soil strata by the freezing and thawing of soils.

Ecofacts – Plant or animal remains, found in an archaeological site, that have not been altered by human hands. Seeds, undressed roof beams, etc., would all be considered ecofacts.

Eluviation – Removal of soluble mineral particles from an overlying soil stratum. Those particles illuviate (see below) in an underlying stratum.

Equifinality – Principle that states that multiple means can produce the same result.

Faunalturbation – Mixing of soil strata by animals.

Footwall – The lower side of a fault face.

Fulvic – A kind of acid often found in soils.

Geliflunction – Very similar to soliflunction, though a result of rapid melt of ice and snow in periglacial regions, where several months' worth of precipitation melts in the space of a few days, waterlogging soils and resulting in soil movement.

Geoarchaeology – Research area that combines archaeology and geosciences to study the geologic, geographic, and earth science topics that bear on archaeological interpretation.

Gleyed soils – Grayish, water-logged, chemically reduced soils. The gray color is a result of oxygen deprivation due to its saturated state. Upon exposure to air, gleyed soils will often develop mottled reddish or yellow colors.

Hanging wall – The upper side of a fault face.

Histosol – A soil consisting primarily of organic materials.

Horizonation – Process of the formation of soil horizons.

Humic – Of or pertaining to humus. Also a kind of acid found in soils.

Humus - Any organic matter that has reached a point of stability where it will break down no further.

Illuviation – Deposition of soluble mineral particles from an overlying soil stratum in an underlying one.

Krotovinas - An animal burrow that has been filled with organic or mineral material from another soil horizon.

Lamellae – Thin, plate-like soil structures.

Laterite – Iron and aluminum-rich tropical soils, usually red in color.

Leaching – Movement of water-soluble soil minerals and organic matter within a soil column.

Midden – A dump for domestic waste.

Mollisols – Grassland soils characterized by thick, dark surface horizons resulting from the long-term addition of organic materials derived from plant roots.

Muskeg – Acidic bog soil found in arctic areas and boreal forests.

Paleoclimatic – Of or relating to the climate in deep antiquity.

Palimpsest - Landscape in which traces of multiple occupations of a site are superimposed directly one upon the other. There is no vertical segregation between them.

Pedogenesis – Formation of soil.

Pedoturbation – Mixing of soil strata by physical, chemical, or biological agents, resulting in homogenized soil profiles.

Plaggen soils – Soils formed in Europe during the Middle Ages by farmers who mixed turves with cattle manure and used as fertilizer.

Podzol – A leached soil found primarily under coniferous forests. They often have a gray or ashy appearance.

Podzolization – Formation of podzols.

Root casts – Calcified structures that are formed in the shape of roots that once existed in soil but have since died and decomposed.

Seismiturbation – Mixing of soil strata by earthquakes and other seismic activity.

Soil horizon - Zones within the soil that parallel the ground surface and have distinctive physical, chemical, and biological properties.

Solifluction – The downhill movement of water-logged soils that lie atop impermeable material (e.g., bedrock).

Stratigraphy - The vertical sequence of strata, whether in soil or sediment.

Stratigraphic profile – The two-dimensional representation of stratigraphy, either in a map or in the vertical face of an excavation unit.

Strike/slip fault – Faults where the hanging and foot walls move primarily laterally instead of vertically.

Taphonomy – Post-burial changes to an archaeological site.

Topography - The surface features of a place or region.

Turves – Plural of turf.