Archaeology as human ecology:
Method and theory for a contextual approach

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For ELISABETH

Beethoven Op. 138 ("Leonore")

Contents

Preface

I have chosen the title *Archaeology as Human Ecology* to emphasize the dynamic interactions between human groups or societies and their environments. This book is intended to provide an introduction to the methodology and theoretical framework for such a study. The central concept is the human ecosystem. This serves as an organizing principle to illuminate the interdependence of cultural and environmental variables, as well as an organizational framework within which to discuss the various scientific approaches critical to understanding the processes of such interaction. The *context* of the book's subtitle refers to both the locus of and the dynamic processes that define human ecology.

The first section, the introductory part of the book, explains and elaborates the ecosystem approach. A second section then develops the three subsidiary fields of study that contribute the substantive data critical to understanding prehistorical and historical human ecosystems: (a) geo-archaeology, the study and interpretation of sediments and physical landscapes; (b) archaeometry, the use of physical and chemical methods of measurement, including raw-material provenance, dating, and site prospecting; (c) bio-archaeology, the study of plant and animal remains that reflect subsistence activities as well as biotic environments.

The third and final section of the book integrates these components within a spatial framework as well as a temporal or diachronic framework. Spatial archaeology can be seen as a fourth field of study, although it is closely interwoven with the others. The spatial dimensions of component data, at different scales (micro, meso, macro), are developed in each chapter, and the spatial paradigm has been chosen to serve as one of the frameworks for synthesis in this final section. This is complemented, in the last two chapters, by theoretical and interpretative discussions within an adaptive paradigm. These deal with the farmers commonly had an impact on the soil-slope-stream system (see Figure 2-2) that was both extensive and intensive and often was of considerable duration. British agricultural landscapes of the Neolithic and Bronze Age were crisscrossed by drainage ditches, partly leveled by low terraces, bounded by earthen or stone walls, and dimpled by burial mounds. Indians in southwestern North America dug irrigation ditches, built dams, and reinforced river banks. In countless situations, prehistorical planters and herders were able to disturb vegetation and ground cover until a threshold was reached at which the amount and speed of runoff were enhanced after rainstorms, filling in ditches and the like by sheetwash and gravity, and truncating or burying soil profiles. In the end, soil formation, slope processes, and stream behavior may have been modified sufficiently to leave a clear record of disturbance, possibly culminating in an episode of landscape degradation, with attendant accelerated soil erosion.

Techniques and procedures

The range of techniques that have the potential to be applied to geo-archaeological goals is derived from several subdisciplines and is therefore almost unlimited. Yet the purpose of geo-archaeology is not to implement an impressive battery of sophisticated tests but to select those procedures that within the constraints of available financial and human resources will yield the results most critical to proper evaluation of a particular context.

Some examples of basic field and laboratory techniques applicable to several stages of analysis (Rapp, 1975; Farrand, 1975*a*; Shackley, 1975; Gladfelter, 1977; Hassan, 1978) are outlined in Table 3-2. They imply that geo-archaeological fieldwork must be carried out inside and outside of the site. They call for repeated revision of research strategies, both during the course of the fieldwork and between seasons. And they mandate multidisciplinary data integration, aimed ultimately toward functional interpretation of sites or site components. Published results should reflect the full range of geo-archaeological and other inputs.

Ultimate collaborative goals

To reiterate, geo-archaeology implies archaeology done primarily by means of earth-science methods, techniques, and concepts. The goal is to elucidate the environmental matrix intersecting with past socioeconomic systems and thus to provide special expertise for understanding the human ecosystems so defined. This task is not an easy one, nor

Table 3-2. *Basic analytical procedures in geo-archaeology*

In the field

The site

1. Recording vertical profiles within the excavation as well as in other adjacent pits or trenches cut in order to clarify the nature of the site sediment sequence and its external contacts.
2. Sampling representative archaeosedimentary materials, as well as nearby natural soil profiles and potential microdepositional analogs, for laboratory study.
3. Relating the site to its landscape by local topographic survey or geomorphic transects.

The landscape

1. Terrain mapping of the mesoenvironment, in conjunction with available aerial photography, detailed topographic maps, and relevant satellite images.
2. Location of other sites and cultural features, preferably in conjunction with systematic archaeological survey, by using geomorphic inference and available aerial photos, possibly aided by geophysical site prospecting.
3. Examination of natural exposures, in terms of stratigraphic subdivisions, sediment properties, and soil profiles, to reconstruct regional landscape history, to provide a wider context for the central site, and to assess possible impacts of the prehistorical community on the environment.

In the laboratory

1. Systematic interpretation of maps, aerial photos, and satellite images to complement field mapping.
2. Sediment analysis for particle size and composition to identify potential geomorphic processes affecting the archaeosedimentary system in time and space and to establish a microstratigraphic sequence both within the site and in the adjacent mesoenvironment; complementary work in mineralogy and micromorphology, as warranted.
3. Sediment analysis for geochemical and biochemical properties such as pH, calcium carbonate content, organic matter, phosphates, etc., in order to assess cultural inputs to the archaeosedimentary system.
4. Provisional modeling of the sequence of site formation, abandonment, and postdepositional change, as well as of spatial and temporal activities during the course of human occupance.

Revision of research strategies

The component and aggregate results obtained in the field and laboratory must be used to reassess the project's research strategies (during the course of a particular field season, if possible, and certainly between seasons).

Multidisciplinary data integration

1. Identification (and, possibly, modeling) of pertinent microenvironments, mesoenvironments, and macroenvironments to establish spatial and ecological parameters for the socioeconomic and settlement patterns suggested by excavation and survey results.
2. Interpretation of the archaeosedimentary system in terms of micropatterning, burial, and preservation of the indicators of human activities on the one hand and biophysical processes on the other.
3. General evaluation of the site or site complex as primary, semiprimary, or secondary.

comprises culturally filtered residues, either surface or sealed, that have been subjected to minimal dispersal and disturbance. A *semiprimary site* consists of such surface or sealed materials that have been subjected to partial dispersal and/or disturbance, but for which relative associations remain essentially intact over at least part of the site. A *secondary site* is composed of archaeological materials that have been subjected to effective dispersal and/or complete disturbance, retaining few informative associations or none. These definitions serve to describe aspects of environmental, not cultural, context. The distinction is essential to avoid a fairly pervasive conceptual confusion. Another qualification to Figure 7-16 is that it does not include all permutations of sealed, surface, primary, semiprimary, and secondary sites. Finally, Figure 7-16 does not consider potential secondary cycles that expose and possibly rebury archaeological residues.

The geochemical flow diagram (Figure 7-16, bottom) deals with the essential preservation processes and products relevant to plant remains, bone, and biochemical residues, particularly as generated in outputs B, C, and D (Figure 7-16, top) (i.e., affecting sealed sites). Organic residues are rarely preserved (or at least discernible) in the case of a surface site.

In combination, the two diagrams of Figure 7-16 provide a geo-archaeological classification for archaeological sites that is predicated on three environmental criteria: (a) surface versus sealed; (b) primary, semiprimary, or secondary; (c) the presence or absence of (and selective preservation of) organic residues. For example, the content of an Egyptian tomb might be BA′ (primary, sealed, with complete organic preservation), that of a Danish bog CB′ (semiprimary, sealed, fairly complete organic preservation), that of a French river gravel DC′ (secondary, sealed, with some organic preservation), and that of an Archaic field scatter EE′ (secondary, surface, essentially no organic preservation).

In conclusion, it may be argued that a proper understanding of the environmental modification of archaeological residues is or should be a critical goal in geo-archaeological study. Unless these processes are first elucidated, the cultural transformations may remain unnecessarily ambiguous or even undecipherable. Only when both the environmental and cultural contexts of a site are understood can sociocultural interpretation of the systemic context of a prehistorical community be attempted.

CHAPTER 8

Geo-archaeology VI: human impact on the landscape

Human activity and the soil-sediment system

The impacts of preindustrial human activities are concentrated in and around living areas, but these represent only a small part of a region. By focusing on sites, many archaeologists fail to appreciate the more diffuse but equally real impacts of people on the landscape at large. In the case of prehistorical foragers, these impacts may indeed by subtle and almost intangible, through the use of fire to facilitate hunting, local disturbance of vegetation, inadvertent dispersal of economic plants, and faunal changes as a result of selective hunting pressures (Butzer, 1971*a*). But farmers and herders normally have significant and even dramatic influences on the environment.

Central to this argument is that the vegetation cover and soil mantle provide a critical resource as well as a protective buffer between the atmosphere and the earth's crust. Under normal circumstances, in a humid landscape, rainfall is intercepted by taller plants, which break raindrop impact and prevent direct rainsplash on mineral soil. Organic leaf litter in various stages of decomposition covers the ground and creates a topsoil layer that cushions water impact, while also acting as a sponge to soak it up. The microfauna of the organic topsoil also maintain a spongy soil structure by converting organic residues into beneficial by-products, enhancing the aeration essential for good plant growth, and allowing water to infiltrate the soil. This diverts surface water from rapid runoff to slow lateral "throughflow" or to recharge the deeper-seated groundwater. Meanwhile, the rooting network helps bind the soil. The net result is that surface runoff is reduced in amount and velocity, soil moisture is enhanced, and groundwater seepage is maintained, even during drier times of the year (Figure 8-1). Stream discharge immediately after heavy storms is reduced or delayed, and dry-season flow is sustained. In this way, vegetation and soil not only condition productivity but also regulate the hydrological cycle. Human activi-

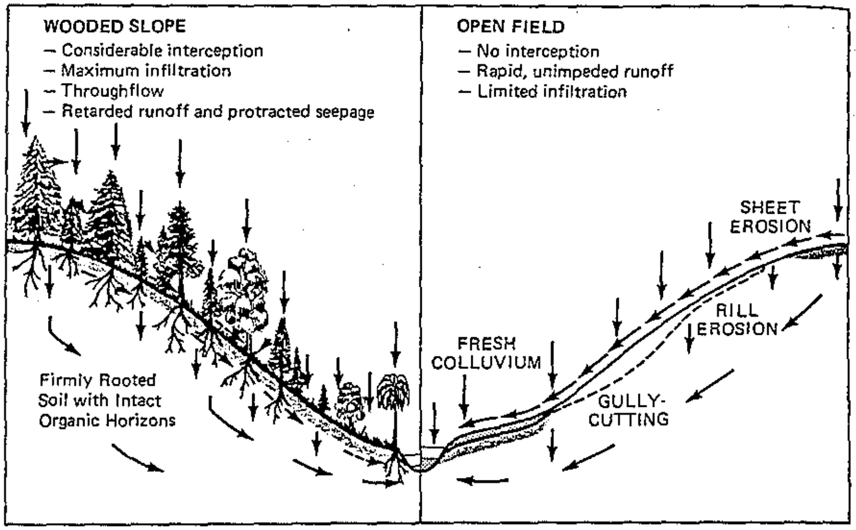

Figure 8-1. Contrasting runoff and infiltration on wooded slopes and cultivated slopes. From Butzer (1976*a*:Figure 6-2) (copyright © 1976 by Karl W. Butzer. Reprinted by permission of Harper & Row, Publishers, Inc.).

ties, however, are consciously or inadvertently focused on the biosphere. Consequently, depending on their intensities, these activities can modify or eliminate both vegetation and soil and thus interfere in the hydrological cycle. The resulting impact can be as dramatic as a climatic change in triggering readjustments by the environmental subsystem that regulates water, soil, and geomorphic processes (see Figure 2-2).

The components of such disturbances can be detailed as follows:

1. *Devegetation*. The native plant cover can be partially or completely removed, initially from local areas, eventually from much of the land surface, by a variety of processes: deforestation, field clearance, grassland burning, animal grazing, substitution of monoculture of an exotic crop, favoring a simplified secondary vegetation intensively grazed or browsed by domesticated animals (Figure 8-1). Leaf interception of raindrops is reduced by the cutting, burning, and browsing of trees and woody shrubs, and vegetative ground cover is reduced or removed by digging, hoeing, plowing, close grazing, and animal trampling. Even after human abandonment, forest regeneration is impeded by fire, grazing, and competition with light-loving plants, favoring an

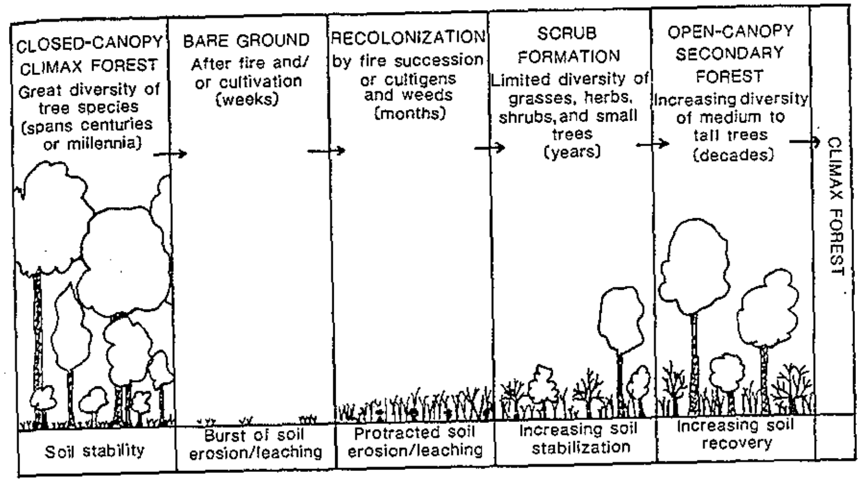

Figure 8-2. Vegetation succession in woodland. Protracted grazing by livestock can lead to an indefinite subclimax vegetation of degraded scrub.

open scrub vegetation or even a "cultural steppe." Such simplified plagioclimax vegetation (Figure 8-2) may be poorer in plant foods (fewer arboreal fruits and legumes, but more tubers and berries), and on low-nutrient soils it may lead to expansion of less nutritious grasses that are higher in cellulose content.

2. *Soil loosening*. Cultivation is designed to break the sod by cutting and tearing up the cohesive rooting network and by loosening the soil and exposing the now more friable soil aggregates to the elements. The hooves of domesticated stock also damage the sod and, together with close grazing by animals such as sheep, impair the regenerative qualities of the vegetative mat, helping to compact the soil and reduce its ability to absorb water (Figure 8-3). Loosened exposed soil is highly erodible, and its organic matter is rapidly oxidized in the sun; when abandoned, such soil tends to compact. Soil that has been compacted allows less water to percolate during rainstorms, accelerating surface runoff and favoring soil erosion.

3. *Soil-water and groundwater changes*. Devegetation and soil deterioration have important secondary effects on soil moisture. In cool wet environments with low-nutrient soils, removal of forest reduces plant evapotranspiration and raises the already high water table; furthermore, deforestation reduces soil biota, increases soil acidity, and thus favors leaching of soil nutrients. As a consequence, acid-tolerant plants

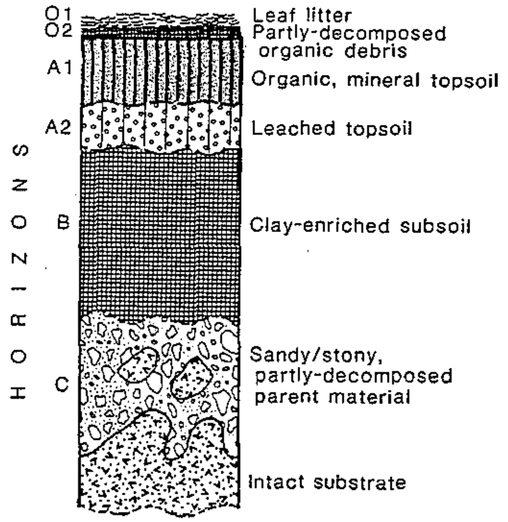

Figure 8-3. A standard soil profile. Plowing destroys the 01 and 02 horizons and degrades the A1 horizon. Once the A2 or B horizon is exposed, the soil is highly erodible. Modified from Butzer (1976*a*: Figure 4-6).

such as spruce, heather, and mosses expand, reinforcing the trend toward acid soils in which "raw" humus accumulates (Figure 8-4A). Seasonal dehydration of exposed soil leads to irreversible dehydration of iron and aluminum oxides, favoring subsoil hardpan formation and further impeding proper internal soil drainage (Figure 8-4B). Eventually, infertile and waterlogged cultural podsols, peats, and heath soils are generated, creating soils that are marginal or unsuitable for agriculture, while favoring an acidic vegetation of little grazing value. In this way, extensive cultural wastelands (moors and heaths) were formed in northwestern and northern Europe, particularly in montane environments and on sandy substrates (Simmons and Proudfoot, 1969; Evans, 1975:Chapter 5; Moore, 1975). In drier environments, the effect is reversed, but almost equally deleterious. Devegetation, dehumification, and reduced soil aeration and infiltration capacity, as well as accelerated surface runoff, all favor reduced percolation of rainwater into the subsoil and down to the groundwater. Water retention in the soil decreases, and the groundwater table drops, reducing spring discharge and cutting off much of the water supply to streams that otherwise would maintain a base flow during the drier spells between rains. Stream flow is less dependable, and sources of drinking water may be

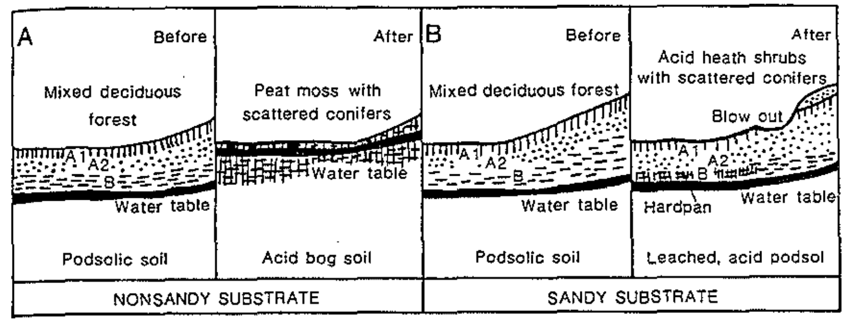

Figure 8-4. Changes in acid soils of cool wet environments resulting from fire clearance or cultivation. The secondary peat moss of A grows upslope as a blanket bog, and the secondary heath mat rests on highly erodible A2 horizons prone to deflation if disturbed.

curtailed; agricultural productivity is reduced on drier soil substrates poorer in beneficial soil biota (Figure 8-5). More aridic soil types expand as part of the cultural steppe (Ložek, 1975, 1976).

4. *Construction*. Human interference in the ecological balance is progressively intensified by building activities and the like. Rainfall deflected from roofs is concentrated on the disturbed ground around buildings. In the case of built-up towns, the increased and concentrated runoff is most erosive along the town perimeter (Figure 8-6). Areas around rural waterholes and wells are other foci of erosion. Unpaved roadways and trails are swept by runoff and often are converted into water-rilled surfaces and even gullies, whereas paved roads concentrate runoff along their margins, and road "cuts" are prone to mass movements and undercutting or rilling. Field terraces on hillsides and sloping valley bottoms are designed to be protective, but when they are no longer maintained, the loose surface soils as well as the rock walls and retainers can be rapidly swept away, with great destructive effect. Irrigation ditches trap sediment on low gradients; when abandoned, they channel and accelerate erosive forces on steeper inclines, much as do artificial drains. Dams lead to premature deposition of fine organic and mineral residues, depriving downvalley floodplains of sediment and natural fertilizers; when dams eventually collapse, the escaping waters can exert unusual erosive force and can pose safety hazards for crops, livestock, and humans. In effect, modification of landscape geometry (Moss and Walker, 1978), even in nonindustrial societies, implies interference in the harmonious adjustment of the innumerable components of a three-dimensional surface. Water attack

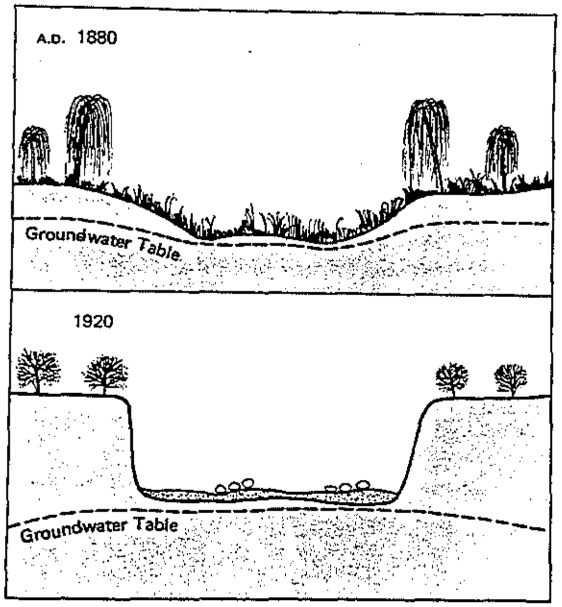

Figure 8-5. Consequences of soil erosion, gullying, and falling water tables in New Mexico A.D. 1880–1920. From Butzer (1976*a*:Figure 7-11) (copyright © 1976 by Karl W. Butzer. Reprinted by permission of Harper & Row, Publishers, Inc.)

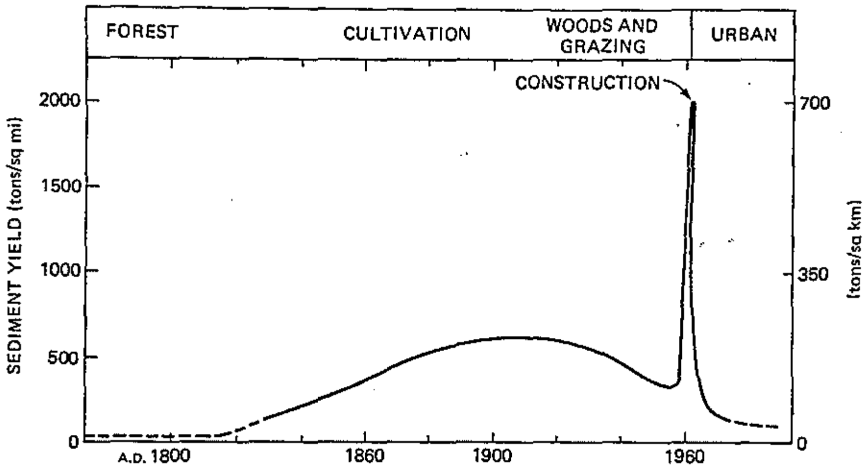

Figure 8-6. Effects of cultivation and urban construction on sediment removal from a Maryland watershed A.D. 1800–1965. Modified from Wolman (1967).

becomes focused on many weak points, leading to various degrees of hydraulic maladjustment.

5. *Accelerated soil erosion*. Devegetation exposes the soil to rainsplash and sheet erosion, effects intensified by cultivation, especially plowing, which destroys the sod and rooting system. On inclined surfaces, initial cultivation can lead to a burst of soil erosion, during which fine-grained suspended material is not only flushed off the slope but often swept away into distant streams. If more compact or stony substrates are intersected by erosion, or if fields are abandoned, a degree of stabilization is restored after a few years. But repeated plowing continues to bring up highly erodible fine soil to the surface, inevitably causing soil impoverishment as clay and organic matter are selectively removed (Moss and Walker, 1978). Sheetwash will affect the whole surface, but more concentrated and more potent rill erosion can develop on lower or steeper slopes, often aided by plow furrows. As rills grow, they may excavate deep gashes that then develop a momentum all their own: As water pours over the rim, it accelerates, plunging into the depression with enough energy to excavate and remove even heavy particles; the gash deepens and begins to eat back, forming a self-perpetuating gully; eventually gullies form intricate networks that continue to deepen and cut headward at a rate of up to several meters during every storm, eventually destroying whole landscapes that become unusable for agriculture (Figure 8-7). Mass movements, including soil creep and slumping, are already set in train or are speeded up by animal trampling on slopes of 5° or more; once gullying is under way, slumping and massive soil collapse continue to aid and even accelerate gully development. Mudflows can also sweep along heavily disturbed silty slopes, transporting even cobbles and blocks, as whole hillsides are set in motion. A last agency is deflation, which attacks dry incohesive soils during long summer droughts (Figure 8-1B), particularly in semiarid environments.

The sum total of processes that remove a soil faster than it can regenerate is called accelerated soil erosion. It is preeminently a cultural phenomenon linked to devegetation and destruction of the sod and organic topsoil by cultivation or overly intensive grazing (Butzer, 1976*a*:114–19). Within a few generations, or even a few years, such accelerated soil erosion can change surface forms and move more soil than can millennia of environmental change (Trimble, 1974; Butzer, 1977*a*). The consequences for productivity are correspondingly enormous, as whole landscapes lose much or all of their topsoil, often

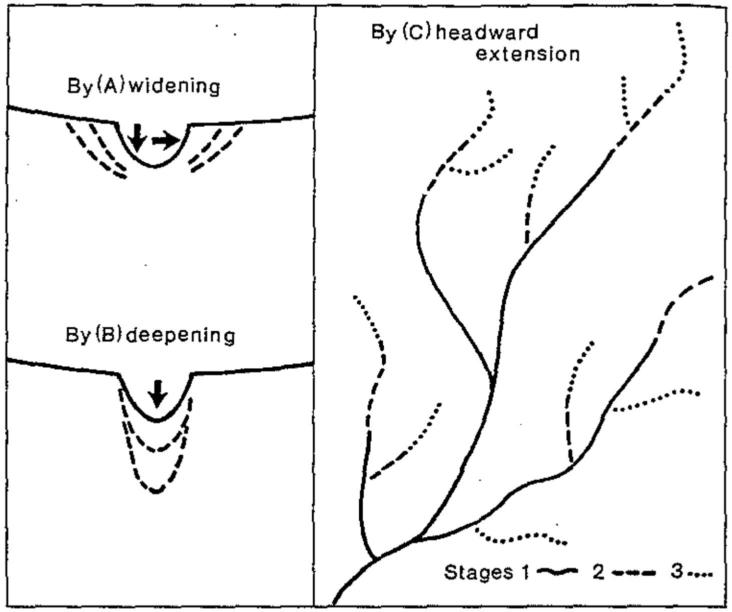

Figure 8-7. Gully enlargement and headward extension.

forcing their conversion to extensive grazing or secondary vegetation. Most, but by no means all, of the catastrophic soil erosion on record is associated with industrial societies. However, cultivation on intermediate slopes over relatively incohesive sediments had already produced equally devastated landscapes in some parts of the Mediterranean world during classical times. Even where the visible impact of soil erosion is less glaring, removal of 20% or 30% of the most fertile topsoil has a drastic impact on crop yields. Such conditions were not uncommon in selected areas of prime soil even three to five millennia ago.

6. *Hydrology.* Accelerated soil erosion goes hand in hand with equally fundamental changes in hydrological processes that reduce lowland productivity. A much higher proportion of rainfall runs directly downslope instead of filtering into the subsoil, eroding the surface and eventually depositing masses of increasingly mineral material and often stony material on footslopes and in shallow alluvial fans that bury more fertile lowland soils (Figure 8–8). Floodwaters rise rapidly and destructively, inundating prime lowlands regularly (Gentry and

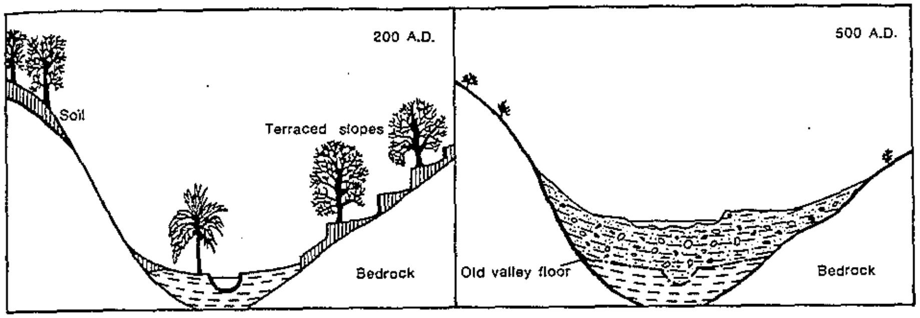

Figure 8-8. An Italian valley before and after stream alluviation as a result of soil erosion in late Roman times. Modified from Butzer (1976a:Figure 7-20).

Lopez-Parodi, 1980). Channels fill in with silt and sand, creating unstable "raised" rivers that frequently burst their banks or change their courses, and water tables rise and favor increasingly waterlogged bottomlands (Figure 8-9). Eventually, large parts of the cultivated lowlands may have to be turned over to grazing as agriculture becomes too precarious and less productive and epidemic disease festers amid expanding tracts of marshy ground.

The malarial coastal lowlands of the Mediterranean Basin were created in this way as much as 2,000 years ago, contributing their share to the economic decline of Greece and Roman Italy.

Another type of hydrological impact can be discerned in the irrigated lowlands of semiarid and desert environments, where seasonal field flooding and incremental irrigation lead to deposition of minute quantities of salt (White, 1973; Worthington, 1978) (Figure 8-10). Because this salt is seldom flushed out of the soil, particularly where the groundwater is high, salinization becomes a widespread process that gradually destroys the agricultural value of lands around the peripheries of irrigation networks, sometimes leading to progressive abandonment (Jacobsen and Adams, 1958; Hardan, 1971; Gibson, 1974; Lisitsina, 1976; Lawton and Wilke, 1979), partly in response to declining river discharge (Kay and Johnson, 1981). Modern salinization of ancient irrigated landscapes further endangers archaeological sites, because salt moves up from the ground water to evaporate at the surface, causing rock to flake off monuments.

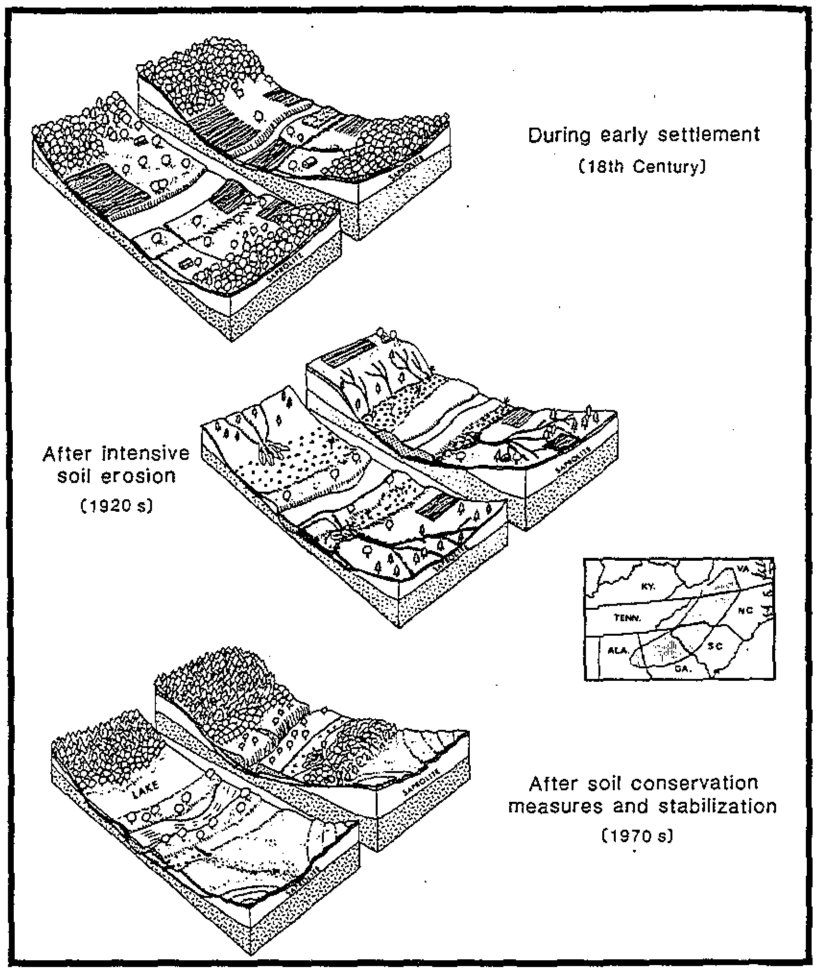

Figure 8-9. Evolution of Southern Piedmont landscapes A.D. 1700–1970. From Trimble (1974:Figure 29) (copyright Soil Conservation Society of America, with permission).

Geo-archaeological indicators of soil erosion

The scenario just described explains a constellation of processes that are symptomatic of an ecosystemic pathology, triggered or exacerbated by human land use. Such landscape changes can be documented in soil

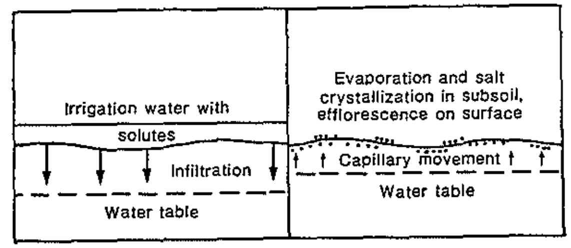

Figure 8-10. Irrigation and salinization.

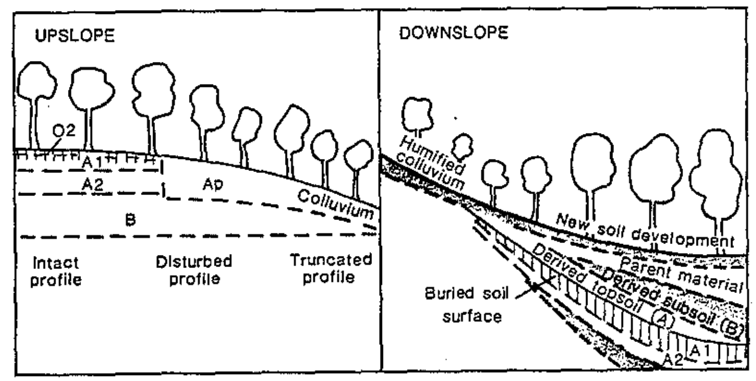

Figure 8-11. Upslope soil disturbance or truncation, and downslope colluvial deposition of soil derivatives in reversed order (strong vertical exaggeration).

profiles and geomorphic forms and sediments, as well as in diverse biological records.

Soil criteria. (a) Disturbed soil profiles. Plowing eliminates the distinctive subdivisions (leaf litter, fermentation, and humic-mineral zones) of the topsoil, creating a distinctive homogeneous plow (Ap) horizon sharply set off from the lighter B horizon below. Often such disturbed profiles can be recognized millennia later, particularly in permanently abandoned farmlands (Figure 8-11). (b) Truncated soil profiles. Erosion of the A horizon, or even part of the B horizon, can similarly be recognized (Figure 8-11), as, for example, in marginal areas of northwestern Europe, abandoned A.D. 1350–1700, where they take the form of fresh, thin A horizons over unusually shallow B horizons (Machann and Semmel, 1970). The remains of deserted farmsteads and villages serve to date such futile attempts at colonization. (c) Redeposited soils.

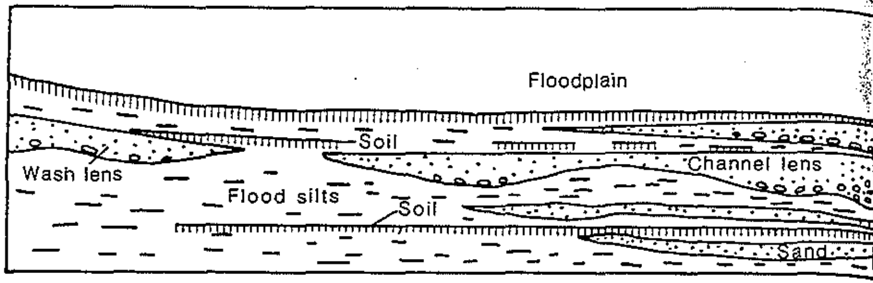

Figure 8-12. Interbedded flood silts, sand lenses reflecting peak floods, and wash lenses may result from sporadic influx of eroded soils and parent material, reflecting cultural disturbance of watershed.

Upslope erosion can bury footslopes, leading to abnormally thick A horizons, or even a reversed sequence of stony parent material over clayey subsoil and organic topsoil, in turn resting on top of a buried but intact profile (Figure 8-11). In some instances, several superpositions can be recognized and archaeologically dated by potsherds (Ložek, 1976). Such field evidence has been discussed further by Limbrey (1975:236–9); see also the work of Cook (1963), Proudfoot (1970), Dimbleby and Bradley (1975), Evans (1975:Chapter 5), Dimbleby (1976), Taylor (1979), and Simmons and Tooley (1981).

Geomorphic criteria. Geomorphic systems respond to soil erosion on various scales, depending on how sustained and widespread the pathologic condition. With the exception of redeposited soils on footslopes, the best traces are preserved in and under floodplains. There temporary stream aggradation may be recorded by lenses of coarse and poorly sorted soilwash interbedded with flood silts or by anomalously thick and extensive increments of such silts, reflecting periods of unusual lateral sediment influx or peak flood recurrence in combination with abnormal quantities of suspended sediments. Periods of renewed stability may be indicated by incipient capping A horizons (Figure 8-12). General stream aggradation typically will favor the development of a higher floodplain along great stretches of river, often documenting shifts in hydrological processes that include higher proportions of sand and gravel, with the result of rapid channel filling. River courses may shift repeatedly, possibly switching from a meandering pattern to an unstable braided system. Such braided channels, linked to prominent sandy alluvial fans at tributary confluences, suggest advanced sheet-

wash and gullying on more distant slopes, where coarser parent materials or wholly unweathered substrates are being exposed.

Eventually, as much of the watershed reverts to secondary vegetation, slopes stabilize, and the sediment supply is drastically reduced. This normally favors new readjustments in hydrological processes and floodplain geometry, with stream entrenchment that leaves the floodplain as a nonfunctional "terrace" several meters above a new and narrower floodplain, more closely approximating the initial hydrological parameters (Figure 8-13). Several such cut-and-fill cycles can create multiple terraces, each of which may coincide with an episode of catastrophic settlement expansion. Soil erosion may also be recorded by coastal siltation in relatively shallow embayments, leading to shoreline progradation out to sea, as more and more sediment is deposited from streams draining disturbed catchments well inland. Shoreline changes of this type, modified in detail by minor sea-level changes and tectonic displacements, are particularly striking in the Mediterranean Basin (Eisma, 1962; Kraft et al., 1977, 1980*a*, 1980*b*).

Geochemical criteria. Lake sedimentation patterns are equally sensitive to land use within a catchment, responding to disturbances by exponential increases in accretions of suspended sediment, charcoal, organic carbon, calcium carbonate, phosphates, and several other ions whose proportions vary according to the regional environment. For example, mid-Holocene deforestation and heath development in the northern uplands of Britain led to increases in potassium, manganese, sodium, and chloride concentrations at the same time that forests were declining, soil acidity was increasing, and suspended sediment was increasing in response to Mesolithic and Neolithic disturbances (Mackereth, 1965; Pennington, 1970). In northern Guatemala, deposition of carbonates and phosphates was accelerated in response to soil erosion and human settlement (Deevey et al., 1979).

Other cations and anions whose deposition may increase under similar conditions are those of ammonia, nitrates, iron, and sulfates. The exact sources of these minerals are difficult to determine with precision, because they may reflect accelerated leaching of disturbed soils, mechanical flushing of soil particulates rich in ions from slopes into a lake, increased human and animal waste effluents, or production by riparian vegetation in polluted waters. In Guatemala, Deevey et al. (1979) noted that silts produced by construction disturbance were unusually low in phosphorus. Another problem is that concentrations

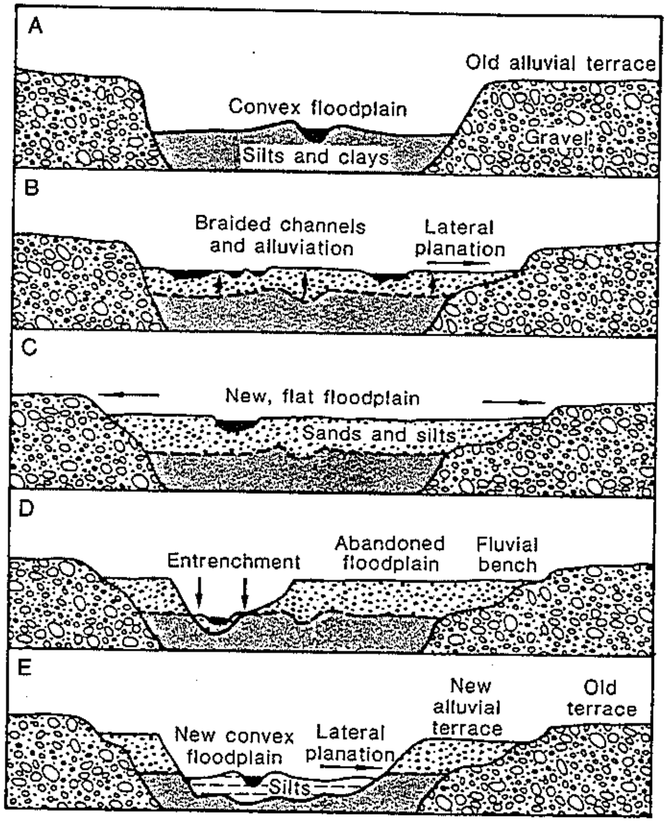

Figure 8-13. Development of an alluvial terrace in five stages. An initial convex floodplain (A) is buried by coarser sediments as a result of rapid alluviation by braiding channels (B). Eventually, a more stable flat floodplain (C) is created by alluviation. Another hydrological change leads to downcutting in alluvium (D) and abandonment of the flat floodplain. A new convex floodplain (E) is established by alluviation of fine sediments and lateral planation, approaching the conditions of stage A. Modified from Butzer (1976*a*:Figure 8-13).

vary with the rate of discharge: Ammonia, chlorides, and sulfates decrease with dilution, whereas turbidity, suspended solids, iron, manganese, and phosphates increase in direct proportion to the volume of water (Ruhe et al., 1980). Despite these difficulties of detailed interpretation, the geochemical records of many lakes preserve a reasonably continuous record that is quite sensitive to land-use processes.

Biological criteria. The biological record of land use may be equally tangible, given good conditions of organic preservation. Palynology has shown the impact of clearance and cultivation in Britain, Denmark, and the Netherlands through replicated "fire successions," with a temporary decline in arboreal pollen, followed by ephemeral peaks in the pollens of pioneer light-demanding plants, cereals, and weeds (Smith, 1970; Evans, 1975:Chapter 6; Groenman-van Waateringe, 1978) (Figure 8-14). Palynological work has also exonerated prehistorical peoples of culpability in some forms of biotic change. For example, a detailed 1,000-year record of vegetation and charcoal horizons in the forests of northeastern Minnesota has shown that fires there had natural origins, that their frequency increased during times of warmer climate, and that artificial fire protection in recent decades has led to changes in forest composition (Swain, 1973). The implications are that not all fire successions can be attributed to human action and that fire is an integral part of most natural ecosystems. Long-term human transformations of biota have been documented in Czechoslovakia, where deforestation, soil erosion, and progressive "steppification" of the landscape favored replacement of a mixed woodland open-country molluscan fauna by an increasingly xeric one during the course of 5,000 years of human occupance (Evans, 1972, 1975:116–21; Smolíkova and Ložek, 1973, 1978). For further discussion of biotic criteria, see Chapters 10 and 11.

Soil erosion in the geo-archaeological record

Soil profiles and alluvial fills can provide sensitive records of the indirect effects of severe human impact on the landscape. Their systematic examination is imperative in dealing with the archaeology of agricultural and pastoral groups. Good case studies of relatively early human disturbance in the geo-archaeological record are available for Europe. Several of these clearly predate the advent of agricultural settlement.

At Lepenski Vir, above the Iron Gates of the Danube in northeastern Yugoslavia, Brunnacker (1971) has documented how, in the Mesolithic village at this location (ca. 7500–6800 B.P.), house-floor leveling cut into existing soils, thus leading to colluvial reworking of sands, with eventual slumping of exposed sediment faces and formation of meter-thick lenses of humic cultural debris. The Neolithic village (ca. 6800–6300 B.P.) at Lepenski Vir intensified these processes until sheets of humic sand, slope rubble, and cultural debris as much as 1.8 m thick

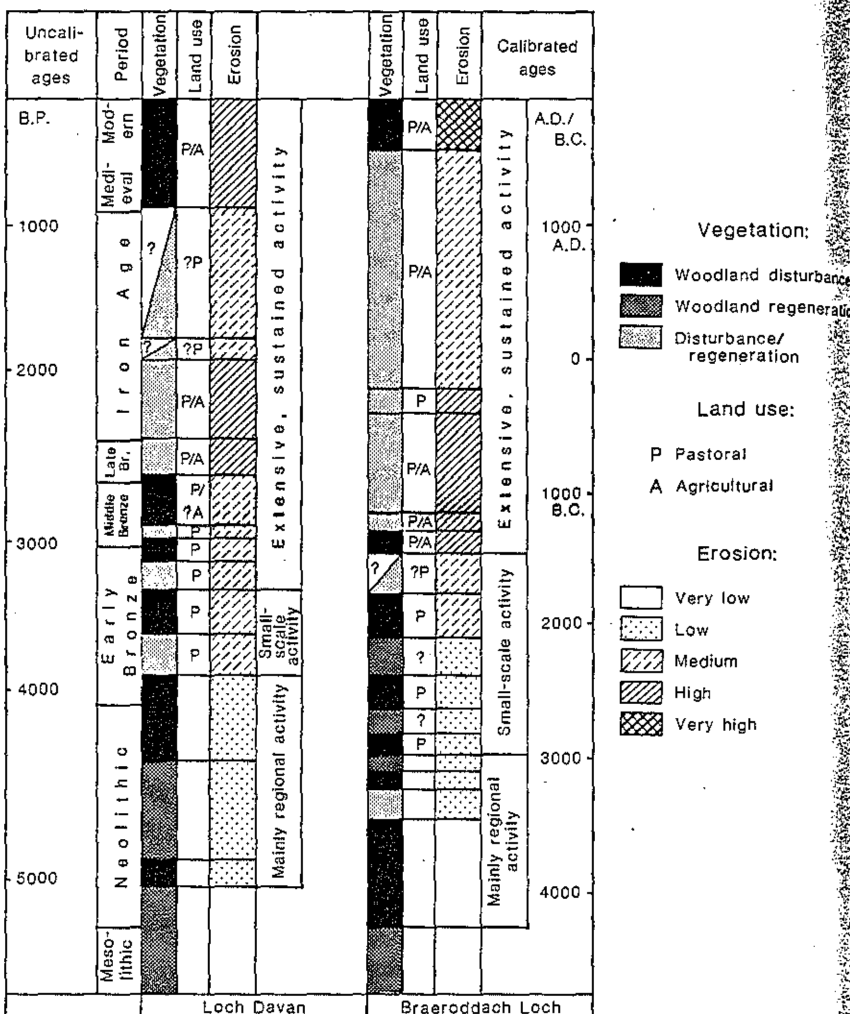

Figure 8-14. Records of vegetation, land use, and soil erosion in two lake cores from northeastern Scotland. Modified from Edwards (1979:Figure 1).

spread extensively around the site. Similar Mesolithic impacts have been documented in Britain, where repeated occupations at Oakhanger (Hampshire) led to burning of the deciduous woodland (abundant charcoal) and then site burial by eroded sand, ca. 6300 B.P. (Rankine and Dimbleby, 1960). At about this time, another Mesolithic occupation

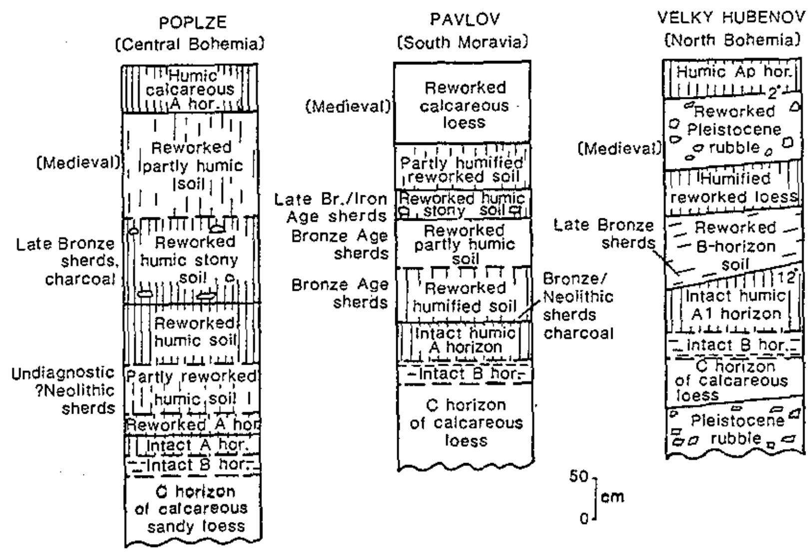

Figure 8-15. Soil and colluvial profiles from Czechoslovakia reflecting Neolithic, Late Bronze Age to Iron Age, and medieval disturbances and soil erosion. Modified from Ložek (1975) and Smolíkova and Ložek (1973).

at Iping Common (Sussex) led to deforestation, heath formation, and, indirectly, soil deterioration that eventually favored eolian activity (Evans, 1975:97–9). It appears that Mesolithic disturbance was highly localized and probably was due to the use of fire for the clearing of undergrowth (to spot game more easily) or in game drives (Simmons, 1969). The effects were temporary, except in marginal environments such as on wet uplands or nutrient-poor sands, where acidity increased and heath displaced forest, intensifying soil deterioration: Peaty bog soils developed on wet ground, and badly leached podsols, prone to erosion, developed on sand substrates.

Early Neolithic to Early Bronze farming activities are being increasingly detected in pollen diagrams and soil profiles of temperate Europe (Simmons and Proudfoot, 1969; Pennington, 1970; Smith, 1970; Evans and Valentine, 1974; Ložek, 1976; Slager and Van Wetering, 1977) (Figure 8-15). Such disturbance was invariably local, resulting in some sheet erosion, with sporadic colluvial deposition in low-lying areas and occasional mobilization of slope rubble in hilly terrain. The widespread diffusion of the plow, accompanied by rapid demographic expansion during the Middle and Late Bronze Age, had more general repercussions on the landscape after 3500 B.P.: extensive deforestation, cultivation, and floodplain aggradation (Ložek, 1976; Brunnacker, 1971, 1978*b*; Butzer, 1980*a*; Richter, 1980). There is evidence of stabilization and renewed soil formation by 2500 B.P., followed by another wave of slope soil erosion and valley alluviation after A.D. 100 in areas of concentrated Roman settlement (after A.D. 750 in landscapes east of the Rhine and Danube affected by medieval settlement expansion).

In the Mediterranean Basin the picture is similar, with local evidence of vegetation disturbance (oak woodlands degraded to Mediterranean scrub) beginning in Late Neolithic or Early Bronze times, but becoming commonplace between 3800 and 3100 B.P. in different areas, as soils were destroyed and valley fills aggraded (Eisma, 1962; Judson, 1963; Van Zuidam, 1975; Faugères, 1979; Davidson, 1980*b*; Van Andel et al., 1980). A second wave of soil erosion that was almost universal and sometimes catastrophic began in response to abandonment of terraced hillsides between A.D. 200 and 500; this occurred again later as a result of medieval colonization of more marginal environments (Vita-Finzi, 1969; Butzer, 1980*a*) (Figure 8-8).

A systematic picture of prehistorical human impact on the landscape has not yet emerged for other continents. However, some examples can be cited. At the Koster site in west-central Illinois, rates of colluviation were 50% higher than background levels during the phase of most intensive Archaic occupation (Horizon 6), ca. 5500 B.P.; disturbance of slope vegetation and soils by food-procurement activities as well as on-site habitation activities may well have been responsible (Butzer, 1977*a*) (Figure 8-16). Around Tepic, in western Mexico, three episodes of soil erosion have been identified and linked to phases of successively expanded agricultural land use, the most recent of which was historical (Cook, 1963) (Figure 8-17). The Tepic record is based on truncated soil horizons, relative degrees of soil reconstitution, and multiple cut-and-fill cycles that permit determination of local settlement concentrations. In northern Guatemala, lakes Sacnab, Yaxha, and Quexil record intensifying agricultural land use through exponential increases in their contents of grass pollen, clay, organic matter, carbonates, and phosphates since about 3500 B.P., correlated with demographic expansion until about a millennium ago (Deevey et al., 1979; Harrison and Turner, 1978). These New World examples serve to show that intensive land use and landscape degradation were not limited to European areas affected by plow agriculture.

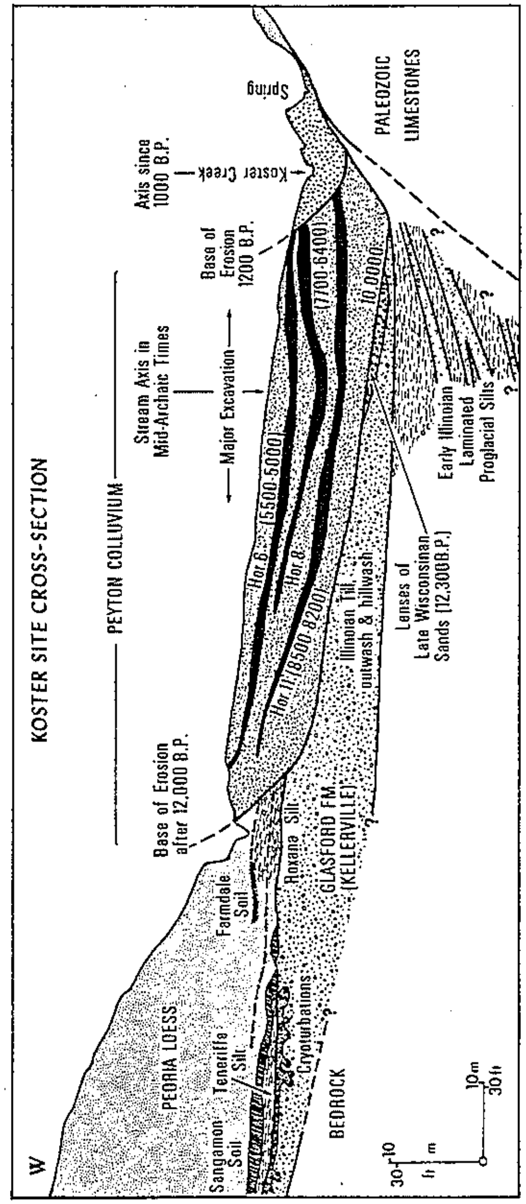

Figure 8-16. The major Archaic occupations (black horizons) in the loessic Peyton colluvium at the Koster site, west-central Illinois. Soil erosion on slopes was due to environmental conditions, but cultural acceleration is probable for at least horizon 6. From Butzer (1977*a*:Figure 2) (copyright Illinois State Museum, with permission).

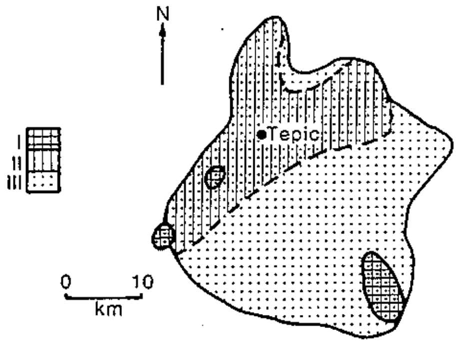

Figure 8-17. Settlement phases at Tepic, west-central Mexico, defined by soil-erosion criteria and pottery dating. Modified from Cook (1963:Figure 11).

A case study of accelerated soil erosion: Axum, Ethiopia

The preceding discussion illustrates the geo-archaeological impact of human land use at the general level, and it can be complemented by more detailed examination of a specific site from another continent, Africa. Axum, in northern Ethiopia, provides a good model. The urban geo-archaeology of that city in the first millennium A.D. was outlined in Chapter 6. Landscape changes affecting the surrounding drainage basin will be considered here (Figure 8-18) (Butzer, 1981*a*).

Axum is located on the piedmont of a group of volcanic hills, in the valley of a small drainage system (4 km^2) that descends steeply from 22° to 45° hillsides onto 2° to 5° footslopes. Profiles were studied in a range of excavated sections and natural exposures: within the former city center (Stele Park, Debterá), along the length of the local stream (Enda Kaleb in headwaters, Mai Shum about midway, Enda Iyasus just upstream of Stele Park), and, on a transverse axis, on the piedmonts west and east of Axum.

The constructional debris indicated in Figure 8-18 includes artificial terraces and their fills, architectural remains, collapse rubbles, and mixed and partially reworked cultural debris (see Chapter 6). The gradation to the category of soil wash is a continuous one at Axum. The preeminently colluvial deposits singled out in Figure 8-18 include redeposited soils, water-laid soil mixed with cultural debris, and reworked collapse rubbles. The alluvial categories represent fine and coarse-grade stream-laid deposits, including silts and clays once carried in

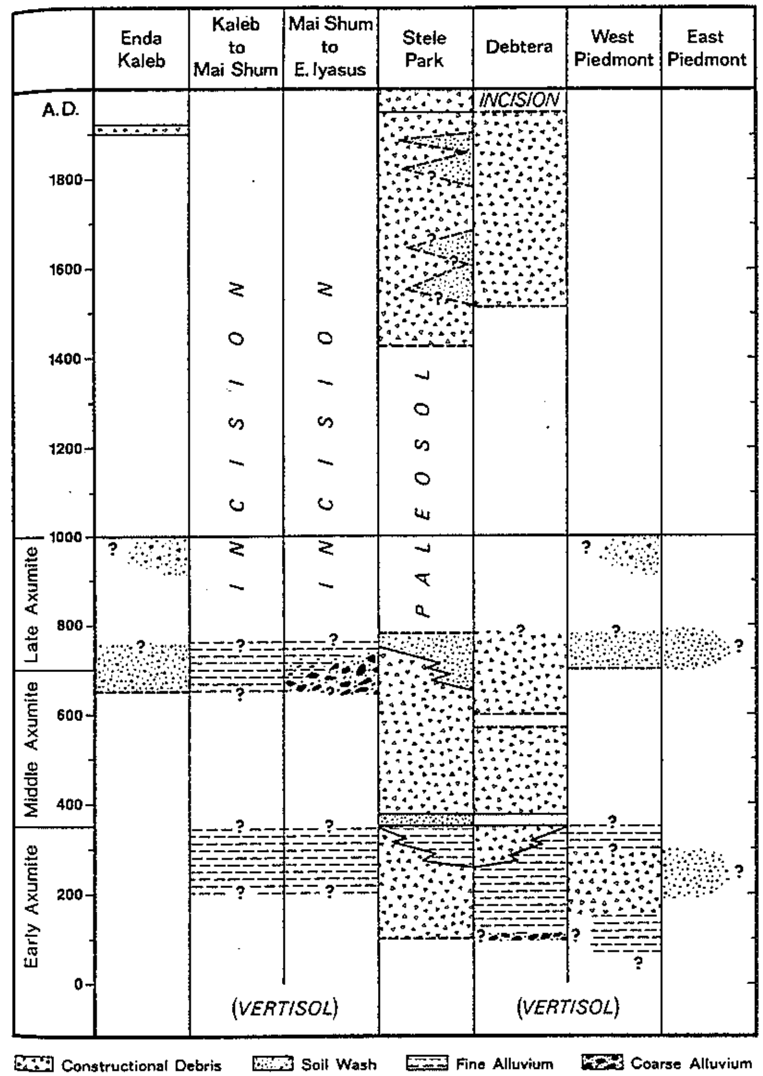

Figure 8-18. Geo-archaeological synopsis for Axum, Ethiopia. Modified from Butzer (1981*a*:Figure 4).

suspension, sands and gravels carried by bed traction, and intermediate deposits of mixed grade, such as sand-silt and sand-clay combinations with pockets, lenses, and isolated pebbles.

The oldest valley-floor surfaces around Axum comprise basal dark alluvial clays and the related heavy soils found over bedrock along the western piedmont. These cracking montmorillonitic clays delimit seasonally wet surfaces that predate Axumite settlement.

The first aggradation (phase I) coeval with Axumite settlement began about A.D. 100 and terminated A.D. 350 or so. This accumulation includes the reworked gray brown clays trapped in unit 2e of Stele Park (see Figure 6-4), prismatic brown clay under the Debterá, brown soilwash and rubble of the western piedmont, and reddish slope loams along the eastern piedmont (Figure 8-18).

This array of early Axumite deposits suggests strong periodic floods, wet slope soils, and seasonally abundant moisture. Deposition of one to two meters of relatively fine sediment across the local floodplain and over much of the adjacent piedmonts implies vigorous mobilization of material through a large part of the watershed. This much accumulation within one to three centuries implies culturally accelerated soil erosion in response to partial devegetation, deterioration of ground cover, an increased ratio of immediate surface runoff after rains, and higher peak discharge. But the sediments of the floodplain and the eastern piedmont also suggest a dramatic shift in slope equilibrium controls related to heavier rains or greater seasonal periodicity of runoff. In the context of intensifying land use in Early Axum, I would argue for a coincidence of cultural and acultural inputs into the environmental system. The composite result was a rapid change in the soil landscape that, by overall evaluation, did not significantly change potential soil productivity.

The second aggradation (phase II) began about A.D. 650 and lasted 150 years or so. Included are water-laid soil and cultural debris of the upper watershed (Enda Kaleb), crude gravels and brown sand loams of the Mai Shum valley sector, reworked cultural debris in Stele Park (see Figure 6-4), stony colluvial soil on the western piedmont, and redeposited slope soil along the eastern piedmont (Figure 8-18).

These Middle Axumite to Late Axumite deposits also have a modal thickness of one or two meters, but the sediment character differs from that of aggradation I. There is little trace of dark clay derivatives, but there is abundant slope rubble and architectural debris. Some material was reworked by water in very localized settings, but much of it implies vigorous denudation of the slopes above Axum, as, for example, a tongue of cobble and block rubble in a mudflow deposit. This argues for soil and slope instability in response to overintensive land use, particularly on marginal surfaces, combined with widespread field and settlement abandonment. But soil moisture was significantly less than during aggradation I.

The net impact of aggradation II was negative: Many slopes were denuded down to stony substrates that allowed no more than marginal browsing or charcoaling activities; extensive agricultural surfaces atop and just below the volcanic hills were either destroyed or reduced to a small fraction of their agricultural potential; even on the gentler lowland slopes, the more organic and better aerated A horizons were selectively stripped or were mantled with sandy to stony soil derivatives from the base of former soil profiles. The geomorphic evidence for culturally induced environmental degradation is direct; the case for vegetation and agriculture is indirect, but no less convincing.

The third phase of aggradation (phase III) may record little more than a short-term geomorphic readjustment following a late episode of abandonment or deliberate destruction (Figure 8-18).

The final phase of aggradation (phase IV) includes soilwash and debris in Stele Park (see Figure 6-4), reworked collapse rubbles in the Debterá, and twentieth-century excavations and land grading.

Land use and soil fertility

All forms of cultivation have a modifying and, to some degree, destructive impact on soils. Even where soil erosion is minimal or is precluded, soil fertility is prone to rapid and sometimes irreversible change. Fertility is a complex matter related to a variety of factors, each of which can be modified by cultivation or soil erosion (Pitty, 1979):

1. *Mineral nutrients.* The microorganisms of a healthy soil generate nitrogen in the form of ammonia, but cultivation, oxidation, and leaching deplete this supply. Phosphorus, potassium, calcium, and magnesium are produced by slow rock weathering, and the resulting available minerals are recycled back and forth between the vegetation and soil. As a result, devegetation can critically impair the mineral supply, whereas excessive leaching of exposed loosened soil flushes much of what is left into the runoff or groundwater (Likens et al., 1970). Unlike nitrogen, which is naturally replaced when the organic cycle is allowed to recover, phosphorus and potassium are particularly difficult to re-

plenish, so that long-term deficits affect all kinds of vegetative growth, even dominant woodland forms.

2. *Organic matter and microorganisms.* Properly decomposed nonacidic humus is essential to soil productivity, because it combines with clay particles to form molecular aggregates with high valences that link up with and stabilize ammonia, potassium, phosphorus, calcium, and magnesium. This beneficial "mild" humus is produced by the teeming soil microorganisms, of which the better types are very sensitive to dehydration, waterlogging, and acidification. Cultivation reduces microorganic activity, so that crude organic matter is not properly ingested, remaining in raw or acidic form. The reduced pH inhibits the microorganisms even further, and the base nutrients become mobile. As they are progressively lost from the molecular aggregates and replaced by hydrogen ions, acidity increases, and nutrients are washed out or leached. The organic cycle can be restored by allowing natural vegetation or regenerate over 20 years or more, but if the pH has dropped below 5 or so, the damage may be irreversible without application of artificial fertilizer (e.g., lime to raise pH, and mineral bases to allow the growth of plant types that generate nonacidic organic debris). This organic cycle is fundamental not only to retard leaching but also to ensure good permeability, water retention, and aeration – properties implied in the concept of soil structure. These properties again affect the organic cycle by ensuring a beneficial microclimate in the soil: not too dry and not too wet, with adequate aeration, thus allowing the microorganisms to thrive and respire carbon dioxide freely.

3. *Texture.* The basic mineral matrix of the soil is also important, particularly the quantity of clay minerals and the types of clays represented. Clays play two different roles. First, their presence is essential for water retention and for an inherent dynamism whereby soil aggregates expand when wet (retarding excessive percolation and mechanical leaching) and shrink when dry (providing aeration and access for subsequent infiltration by rainwater). Depending on how expandable the clay type is (montmorillonite high, illite intermediate, kaolinite very low), less than 5% to 10% clay is inadequate for proper moisture retention, whereas more than 25% to 50% is excessive, leading to temporary or permanent waterlogging and poor aeration. Organic matter enhances the beneficial properties of clays by an order of magnitude, so that excessive cultivation of clayey soils favors compaction, poor aeration, and temporary waterlogging, reducing vegetative growth and inhibiting microorganic activity. Clays have different valences with

which to hold nutrient bases (kaolinite low, illite high, montmorillonite an order of magnitude higher than kaolinite), a capacity that is also greatly enhanced in clay-humus molecular aggregates. This number of available electrical links for mineral bases is called the exchange capacity; together with the pH, which gives an index of the proportion of available electrical charges that actually hold on to bases, the exchange capacity provides an objective measure of potential fertility. Altogether, selective erosion of clays by sheetwash, let alone destruction of the clayey segments of the soil profile by rill erosion of gullying, will have a catastrophic impact on soil fertility. Because clays form slowly over many millennia, severe soil erosion imposes essentially permanent restrictions on potential productivity.

Altogether, soil fertility is a fragile commodity, and many advanced forms of deterioration are almost irreversible, except with the application of special technology, at great cost of labor and capital investment, seldom available to subsistence economies. Several types of land use in prehistorical times can be expected to have had different effects on sustained fertility and productivity; discussions of these effects have been provided by Clarke (1976), Kirch (1978), and especially Denevan (1978).

The small, scattered, low-density populations of Neolithic Europe appear to have employed the long fallow system, cultivating small dispersed plots for a year or two, then allowing forest regeneration over 20 years or more. This method is generally not precarious: Erosive losses are negligible, soil nutrients and moisture are preserved, and regeneration is rapid. Larger populations can be supported by interposing short fallow periods of 4 to 20 years, generally sufficient to improve soil aeration and restore organic matter and nitrogen, thereby maintaining a reasonable degree of fertility and productivity (Greenland and Nye, 1959). But the simple probabilities of dehydration and sheet erosion are increased, and the typically denser spacing of fields tends to favor more disturbance and overall deterioration.

Bush or grass fallow periods of only one or three years require increased labor input, because weeds and pests become endemic, and maintenance of aeration and soil structure necessitates elaborate hoeing or plowing to loosen and mix the soil. Fertilization techniques probably were not understood by most prehistorical farmers, as suggested by a lack of any documentation from pharaonic Egypt (Butzer, 1976c:89–90). Consequently, declining crop yields were inevitable and progressive soil loss probable. When such plots were eventually abandoned, the leached and often more acidic soils were inadequate for nutrient-demanding trees, favoring a secondary vegetation dominated by different species; in cool wet environments this led to the expansion of acidic heaths or peat bogs. Forest recovery may have been permanently impeded by livestock grazing and deliberate burning, with animal trampling and continuing rainsplash erosion inhibiting soil recovery and accelerating soil erosion. Such increasingly degraded vegetation provides fewer plant types suitable for human consumption and, in competition with domesticated stock, can sustain fewer species of large game animals.

Soil erosion and depletion vary greatly according to the type of soil preparation. Hoe cultivation of small seeding areas breaks up only a fraction of the sod, and modern experiments have shown that such a no-tillage technique can reduce soil erosion to 1% or 2% of that typical for plowed fields, under otherwise identical conditions, with runoff cut to perhaps half (Phillips et al., 1980). Spot hoeing provides lower short-term yields but allows more sustained productivity, not only as a consequence of little or no soil loss but also because soil moisture is retained, seasonal dehydration is less probable, and soil temperatures are lower, with correspondingly less oxidation of organic matter, while soil structure and microorganic activity are maintained.

By contrast, plow agriculture produces higher yields per unit area in the short term and makes subsoil layers accessible to plants by deep plowing. But plowing can readily become an ecological disaster, and even under optimal circumstances erosion and soil depletion are almost unavoidable. Long-term yields can be sustained only by large-scale application of fertilizer – an almost impossible task for subsistence farmers. A third type of agricultural preparation is exemplified in high-productivity gardens adjacent to settlements. Such horticulture is normally predicated on liberal applications of animal and human manure. Good microorganic activity is maintained, and high yields are guaranteed indefinitely. Provided the climate is warm enough and irrigation is applied as necessary, two or three harvests per plot per year may be possible.

Agricultural strategies evidently have involved some degree of awareness of short-term and long-term maximization alternatives. Clearing and preparing the ground on a new plot may involve less work than combating secondary vegetation and pests while maintaining the soil productivity of old plots. The availabilities and effective costs of technology, labor, and new land were and remain major considerations in such decisions. Accordingly, pervasive if subtle modifications are imposed on the landscape.

Careful dating of British lake cores has provided a first approximation for the durations of periods of woodland clearance, cultivation, and regeneration. Small-scale local disturbances of the sort implied by long fallow or short fallow appear to have been too brief to be identified by current methods. Episodes of farming that lasted between 100 and 1,000 years have been documented from various British sites (Edwards, 1979; Turner, 1979). These represent the cumulative record of innumerable local clearances in a pollen source area with extensive and often sustained human activity – probably documenting situations with grass or bush fallow.

Geo-archaeological landscape features

The preceding sections have focused on the significance of human activities for soils, a factor generally underappreciated by archaeologists. It is now appropriate to consider the record of creative human intervention in the landscape (see Chapter 3). Major features of this type can be outlined as follows:

1. Plow (Ap) horizons in areas formerly cultivated but not currently cultivated (Limbrey, 1975:331–2) or buried under the spoil of old ditches, earthworks, or mounds.

2. Spoils from ditches, pits, and earthworks, as well as primary mounds, that bury older surfaces to create paleosols (Dimbleby and Speight, 1969). Loose erodible soil is only partly washed back into artificial depressions, leaving irregularities plainly visible in surface morphology.

3. Infillings of ditches, pits, palisades (postholes), and wells often are visible at the surface or from the air because of their greater moisture retention and richer vegetation, even where compaction has not created a negative imprint. The sediment infillings usually include complex stratified lenses due to textural sorting, mixing, reversal of soil profiles, and multiple humic horizons (Limbrey, 1975:292–9, 304–9; Evans, 1978:112–21; Vermeersch and Walter, 1978) (Figure 8-19). Such surface and subsurface patterns are critical for indentification of archaeological configurations, and at the same time they provide testimony of land-use activities. Gabriel (1979) described a variety of archaeological features from the Sahara that are easily confused with "natural" geomorphic features: subterranean storage pits, smooth rock concavities ground out by milling stones, multiple grooves in rock faces used to sharpen tools, and various geometric stone arrangements representing the remains of occupation structures.

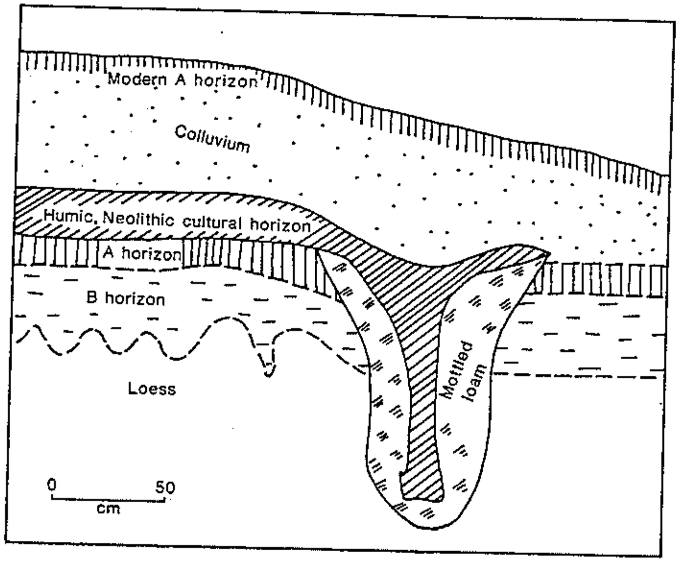

Figure 8-19. Palisade pseudomorph fill, ca. 5250 B.P., at Thieusies, near Mons, Belgium. Modified from Vermeersch and Walter (1978:Figure 3).

4. Prehistorical roadways and trails, even when not traveled by wheeled vehicles and animals, tend to form conspicuous negative imprints on the landscape as a result of accelerated runoff, rilling, and soil erosion. Such depressed linear features, as well as convex, rock-paved forms and rock-cut stairways, also affect vegetation patterns through moisture retention different from that of adjacent fields. Numerous examples can be cited from Italy, the borderlands of the Roman Empire, the Inca highlands of Peru, and the San Juan Basin of the American Southwest.

5. Terraced fields are conspicuous in many irregular and mountainous landscapes of most continents, ranging from Britain (Bowen, 1961; Fowler and Evans, 1967) to Southeast Asia (Spencer and Hale, 1961; Wheatley, 1965) and Latin America (Donkin, 1979). The idea of terracing is to build low rock walls along selected contours or across the lower slope of a field. Material is then excavated from below each such wall to be filled in above the next lower one, creating a stepped surface in which each field floor has perhaps half the original slope gradient. These terraces (called lynchets in Britain) retard runoff and soil erosion (Figure 8-20). Even when partly washed out by severe storms or after

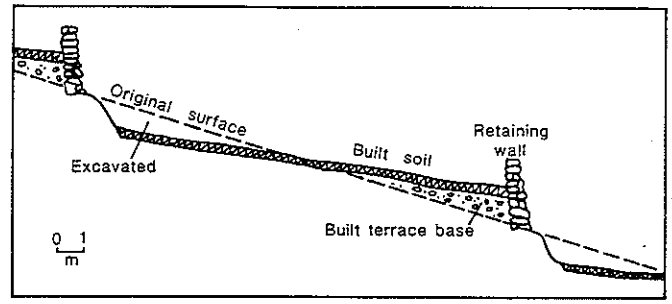

Figure 8-20. Hillside field terrace construction in Mediterranean Basin.

abandonment, such terraces remain conspicuous landscape features over many millennia.

6. Irrigation furrows, ditches, canals, and control gates are prominent parts of the archaeological record in many semiarid and desert settings. Their gross configurations have often been mapped (e.g., from aerial photos) during the course of ground surveys (Adams and Nissen, 1972), but detailed study and reconstruction (Achenbach, 1976; Farrington and Park, 1978) are still the exception rather than the rule. In fact, I was able to identify a small irrigation network during the first day of a visit to a major archaeological project (unnamed here) that had operated for a decade without even recognizing the sand-filled canals.

7. Middens are heaps of archaeological debris, commonly including organic wastes, shell, bone, or ash. They range in size from a few square meters to prominent landscape features 50 to 100 m long and 15 m or so high. Many large middens also served as occupation sites, but the majority of smaller middens were special-processing loci or the refuse dumps of larger settlements. Particularly striking are the coastal middens of some areas, composed largely of molluscan shells or shell residues (Evans, 1978:126–9), with interstitial eolian sand, soilwash, and ash. Another case in point is provided by the so-called snail mounds (*escargotières*) of Algeria and Tunisia, composed of ash, bone, and countless land snails (Hassan and Lubell, 1975).

8. Burials and burial mounds of prehistorical cemeteries also contribute to archaeological topographies, although simple graves tend to be refilled in much the same order as they were opened and can easily be overlooked. Rock piles (tumuli or cairns), megalithic blocks, and earth mounds are far more conspicuous, such as the Bronze Age "barrows" of England, consisting of earth-covered stone-lined burial tunnels

(Evans, 1975:116–17, 132–3). Even more complex is the stratigraphy of the multiple Indian burial mounds built in the central and eastern United States (Schroedl, 1978) (Figure 8-21). Burials may be identified (even when bone has been decomposed) through detailed phosphate analyses (Proudfoot, 1976) or by stain silhouettes identified in plan section (Biek, 1970).

9. Prehistorical flint mines were important in Britain and Belgium (De Laet, 1972; Evans, 1975:124–8; Bosch, 1979; Shepherd, 1980) and elsewhere. Most striking are large pits cut through soft overburden down to flint-bearing limestones, sometimes involving deep shafts that honeycomb the bedrock as much as 20 m below the surface. Such mines and their associated spoil heaps remain visible even after partial refilling (Figure 8-22). Bronze Age and Iron Age mines for critical ores tend to be even more elaborate, and the related slag from furnaces can be prominent in the geo-archaeological record.

10. Artificial soils are not unusual in some marginal agricultural environments in Europe, particularly in reclaimed fens, bogs, and tidal marshes along shorelines and poorly drained floodplains. Complex examples include drainage ditches, protective dikes, wood-plank roadways and revetments, and raised agricultural plots, first reinforced by ditch spoil and then veneered with imported mineral soil and organic fertilizers (Slicher van Bath, 1963; Limbrey, 1975:335–41). Underlying peat moss may first be cut away for use as fuel. This technique, in its more elaborate forms, continued in use through medieval and modern times as more and more marshland was settled. Artificially raised fields, intended to allow cultivation of poorly drained areas, are also widespread in tropical environments (Denevan and Turner, 1974; Turner and Harrison, 1981).

The various features outlined here provide an overview of the many geo-archaeological indicators that record human activities in the landscape, thus documenting the spatial patterns of settlement. Such features are relatively obvious, both morphologically and analytically, and they should serve to direct attention to the less visible but more universal records of general landscape modification and degradation documented in soil profiles and floodplain geomorphology. One major obstacle in regard to recognition of prehistorical three-dimensional land-use patterns is the increasingly heavy hand of industrial societies exerted on almost every facet of the landscape. A second obstacle is more easily remedied but no less urgent: the widespread disregard of land-use criteria in archaeological research design and methodological discussion.

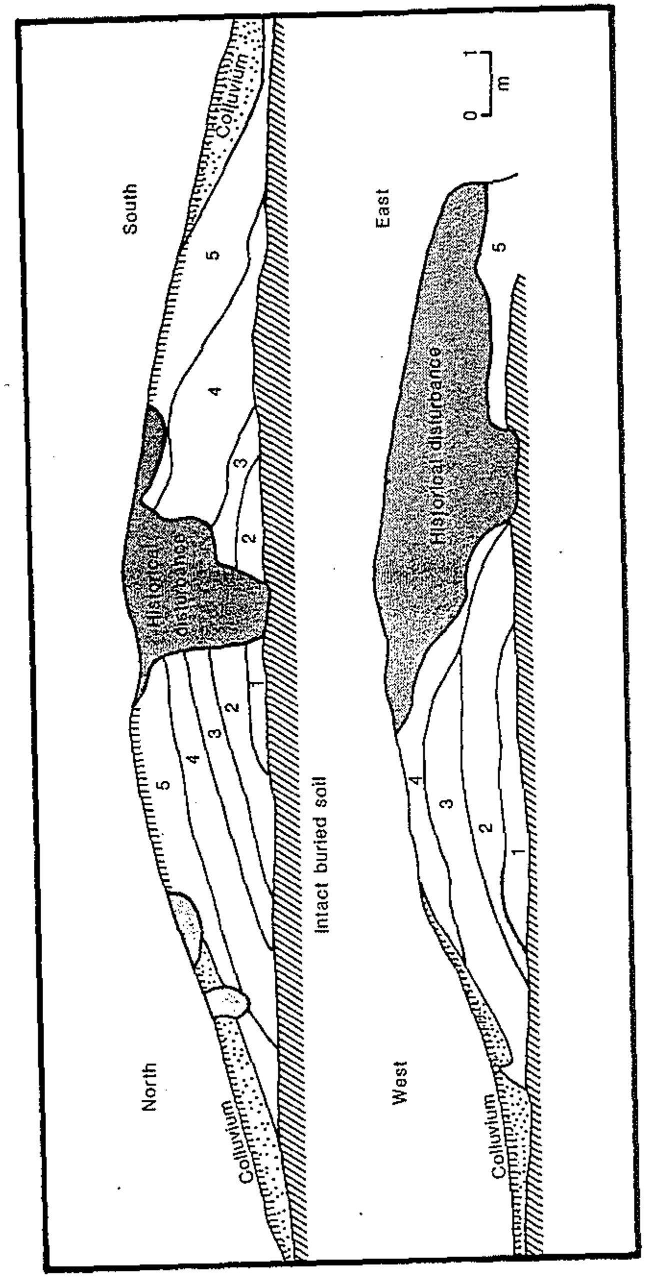

Figure 8-21. Archaeostratigraphy of McDonald site (mound A), east-central Tennessee, showing successive construction phases (1 to 5), tenth to fourteenth centuries A.D. Modified from Schroedl (1978:Figure 35).

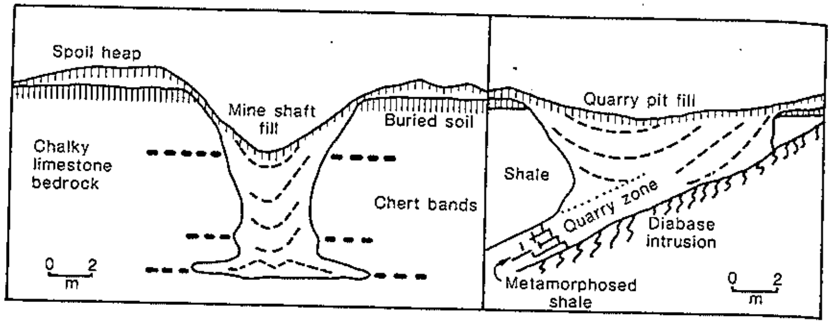

Figure 8-22. Prehistorical chert and indurated shale quarries in Britain. Modified from Evans (1975:Figures 54 and 56).

Landscape productivity and degradation

The human capability to modify the environment implies that the relationship between people and their environment is a reciprocal one. Consequently, in order to keep the subsistence-settlement system in a stable relationship with the environment, resources must not be overexploited. Land use denotes more than an adaptive strategy, because it implies the impact of people on a landscape. The geo-archaeological strategy developed here allows comprehensive assessment of the cumulative direct and indirect impacts of human activities on soils and sedimentation in particular and on ecosystems in general. Such an approach is critical to proper spatial and temporal perspectives on agricultural societies and pastoral groups.

The spatial perspective focuses on understanding the distribution and patterning of activities within a complex mesoenvironment. Such activities must, insofar as is possible, be defined in real inductive terms, such as by implementation of site catchment analysis (Vita-Finzi and Higgs, 1970; Higgs and Vita-Finzi, 1972; Higgs, 1975:223–4). Catchments can be profitably examined and reconstructed by teams of qualified researchers willing and able to employ new recovery strategies beyond the immediate confines of an excavation. The geo-archaeologist, like the modern land-use planner (Davidson, 1980*a*; Morgan, 1979), can devise terrain maps representative of the period of occupation that incorporate data on relief and surface roughness, texture of surficial sediments, and any indicators of intervention in the contemporaneous soil mantle and hydrological processes. Such criteria have significance both for predicting vegetation mosaics, in conjunction with

biological evidence, and for assessing soil moisture, productivity, and erodibility (see Chapter 13). Along such lines, a group of researchers can then generate local models for primary productivity, biomass, and carrying capacity of macroconsumers, as well as the potential yields of cultivated versus gathered vegetable foods and domesticated versus wild animal resources. When these are complemented by appropriate archaeological surveys, a realistic spatial evaluation of prehistorical human activities is at least theoretically possible. Given the realities of research funding and the limited number of qualified experts available, it seems unlikely that such spatial resolution can be achieved in the near future. Perhaps the best we can hope for at the moment are compromise efforts, such as the empirical resource distribution and procurement analyses of Kirkby (1973), Flannery (1976:Chapter 4), and Harrison and Turner (1978).

In regard to temporal perspectives, the geo-archaeological record complements excavation and settlement surveys through its inherent sensitivity to stress in the ecological system. Intact natural ecosystems support complex food chains in which population sizes are regulated so as to maintain similar patterns of energy distribution from one year to the next. In degraded ecosystems, on the other hand, annual productivity fluctuates more strongly, because larger numbers of individuals and fewer different species allow little internal regulation, permitting strong fluctuations in consumer populations (Woodwell, 1970; Odum, 1971). This biological appreciation carries insights for soil landscapes, on the one hand, and human adaptive systems, on the other. Deforestation, grazing, and cultivation create fragile soilscapes that are susceptible to rainsplash, accelerated runoff, reduced infiltration and aeration, periodic dehydration, erosion, and declining fertility. High human population densities are possible, far exceeding those in foraging societies in which people are but a small segment of the consumer community. But agricultural and livestock productivity will fluctuate far more dramatically than that for game and vegetable foods in an intact ecosystem and will eventually decline without massive inputs of technology, labor, and capital. Agricultural ecosystems consequently represent short-term maximization strategies, unless carefully tailored through generations of trial and error to approximate a homeostatic equilibrium. The geo-archaeological record of soil erosion and related cut-and-fill cycles demonstrates that homeostatic equilibrium has rarely been maintained over the long run.

In the Dartmoor region of southwestern England, palynological studies and soil-stratigraphic work have documented progressive, but initially localized, disturbance. Late Bronze Age deforestation and farming then led to widespread soil leaching, acidification, and peat bog expansion that were completed during the Iron Age and thus destroyed most of Dartmoor's productivity (Simmons and Proudfoot, 1969).

In Middle Axumite times, the environment of northern Ethiopia probably had been stripped of most of its export resources, such as ivory, incense, and civet musk. When the disruption of international trade during the seventh century A.D. reduced revenues, Axum lost the wherewithal to control the resources of its border provinces; as a result, intensified land pressure at home led to rapid environmental degradation and essentially permanent destruction of much of Axum's agricultural potential (Butzer, 1981*a*). Similar examples can be cited from contemporary industrial societies, such as the United States, where estimated soil losses over half of the country are double the amount considered compatible with permanent agriculture (Pimentel et al., 1976; Brink et al., 1977). Such modern disturbance has corollary implications for the conservation of archaeological sites: Mechanized agriculture destroys sites, and, indirectly, the high peak discharges of degraded ecosystems favor site erosion or deep burial in the wake of rapid floodplain aggradation.

Geo-archaeological investigation of landscape context can, in conjunction with archaeological survey, elucidate the subtle reciprocal responses of settlement systems and ecosystems through time; it can also identify the drastic and sometimes irreversible modifications of regional ecosystems. The interrelated vegetational successions, the shifts in hydrological regimes, and the modifications in the delicate balance between soil formation and soil erosion are of more than esoteric landscape interest. They reflect significant changes in automorphic productivity, with direct consequences for both animals and people. Long-term adaptive success evidently is predicated on such dynamic environmental variables.

CHAPTER 9

Archaeometry: prospecting, provenance, dating

Scope and purpose of archaeometry

The term *archaeometry* has been in common use since 1958, when the first volume of the journal *Archaeometry* was published by the Research Laboratory for Archaeology at Oxford. The contents of this journal were and have remained technical expositions of physical and chemical methods applicable to dating and materials identification in archaeology. Other periodicals publishing substantial contributions to archaeometry include the *Journal of Archaeological Science* (since 1974) and *Revue d'Archéometrie* (since 1977) (Beck, 1980). A broader array of relevant techniques and applications has been presented in the Brothwell and Higgs compendium *Science in Archaeology* (1970, first edition 1963) and by Brill (1971). Despite some overlap with geo-archaeological and bio-archaeological research, the input of physical and chemical methodologies to archaeology continues to be distinctive. These efforts are here labeled as archaeometry, and three major applications are recognized: (a) subsoil prospecting, (b) materials identification and provenance, and (c) "absolute" or chronometric dating.

The great majority of archaeometric techniques require expensive equipment ranging in price from several thousand dollars to over a million dollars. The work tends to involve time-consuming procedures or highly repetitive manipulations that follow a well-defined routine and can be readily replicated. Many of the techniques can be learned and then applied, with reproducible results, in a comparatively short time.

In these several ways archaeometry tends to differ from geo-archaeology and bio-archaeology, in which equipment needs are modest, but competent application requires long years of experience and innovative adaptation of basic procedures to specific projects. Heavily dependent on observational methods and the comparative approach, geo-archaeological data and interpretations often are disturbingly difficult to repli-