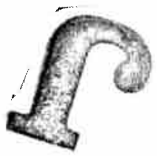
Archaeology as human ecology:

Method and theory for a contextual approach

KARL W. BUTZER

Henry Schultz Professor of Environmental Archeology
The University of Chicago



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CHAPTER 1

Context in archaeology

Introduction

Archaeology is at a crossroads. During the late 1960s and early 1970s, center stage in North American archaeology was reserved not for competing interpretations of historical processes but for discussion of the New Archaeology. This phenomenon can be interpreted as a public debate, generated in no small part by the exponential increase in empirical data during the 30 years prior to 1960. The gathering of facts had become increasingly additive, rather than contributing to a cumulative body of real information. Syntheses tended to be descriptive, simplistic, and speculative. The New Archaeology began as an American intergenerational conflict, as an introspective reassessment of means and purpose. But these painful beginnings, with the new castigating the old, were then followed by constructive debate among a new international generation of archaeologists in regard to goals and the optimal strategies to attain them. The net impact has been healthy, with refinement in the strategies of empirical research and far more sophisticated interpretation.

Nonetheless, the so-called great debate in archaeology also created its own simplifications. By polarizing old and new approaches, the impression was given that archaeologists were either empirical or theoretical. But on closer inspection the small group of active participants in the great debate are seen to be neither pure theorists nor pure deductivists. Archaeology is, by its nature, ultimately empirical. The great debate is far more than a matter of philosophical abstractions. It is a fundamental reevaluation of the conceptual framework of archaeological research, a quest for a paradigm that will rationalize both the laborious data gathering and the frustrating interpretative activities of the discipline.

Those in the swelling ranks of the emerging consensus are of one mind in only one essential matter – that fresh and more productive vistas must be opened. The great diversity of possible innovative approaches is illustrated by the many articles and books, ranging from ethnoarchaeology to computer simulation, that appeared during the 1970s. They suggest that archaeologists have begun to opt for a pluralistic paradigm in their search for better insights and that a rapid radiation of new research directions is under way. The majority of these trends reflect an intellectual confrontation with several facets of cultural anthropology. There also is a considerable debt to the discipline of human geography, in particular to spatial theory. What remains poorly articulated is the equally fundamental environmental dimension.

Ironically, environmental archaeology is one of the oldest interdisciplinary bridges in the field. Archaeologists have always been conscious of environmental context, and from the earliest days diverse groups of scientists have participated directly or indirectly in excavation. Compared with some 5,000 individual members of the Society for American Archaeology, there are about 500 members in the new Society for Archaeological Sciences, with little overlap in affiliation. This surprising ratio suggests substantial empirical input from those involved in the applied sciences, who nevertheless have little impact on the dominant intellectual currents within archaeology.

Perhaps the environment is taken for granted. Certainly the environment is specified as a variable in most processual equations, but in all too many instances such an equation is then resolved by treating that variable as a constant. Also, archaeologists often take a static, classificatory approach to the environment, even when the human variables happen to be considered as part of a dynamic system.

It is my belief that the concept of *environment* should not be considered synonymous with a body of static, descriptive background data. The environment can indeed be considered as a dynamic factor in the analysis of archaeological context. The basic ingredients of archaeology are artifacts and their context, ranging from food residues to sediment and landscape matrix. The term *context* means many things to many people, but the word is derived from the Latin verb *contexere*, "to weave together" or "to connect." For archaeology, context implies a four-dimensional spatial-temporal matrix that comprises both a cultural environment and a noncultural environment and that can be applied to a single artifact or to a constellation of sites. Context, so defined, is a primary focus for several approaches within archaeology. For example, spatial archaeology is concerned with horizontal patterning of aggregates within a site as well as with interconnections between sites. Context also has long been the focus for archaeometry, which is concerned with temporal frameworks, materials analysis and technology, and raw-material sources. But most important, context has been the traditional focus for a poorly defined but wide-ranging enterprise sometimes described as environmental archaeology, including such specializations as archaeobotany, zoo-archaeology, and geo-archaeology.

In an excellent introductory text, Evans (1978:xiii) defined environmental archaeology as "the study of the past environment of man." He specifically emphasized techniques and indicators useful in reconstructing the environments of ancient human communities, as well as the applications of such techniques. This definition is not only narrow but also unacceptable.

To use an analogy, the distinction is between geological archaeology and archaeological geology. To me, archaeological geology is geology that is pursued with an archaeological bias or application. This is fundamentally distinct from geological archaeology, carried out by means of geological methods, techniques, and concepts, but constituting what is first and foremost an archaeological endeavor (Butzer, 1977*c*). At issue are the goals, rather than the techniques.

I have long held the view that our ultimate goal is to determine the interrelationship between culture and environment, emphasizing archaeological research "directed toward a fuller understanding of the human ecology of prehistoric communities" (Butzer, 1964:vii, 5). But in the early 1960s such relationships proved difficult to identify, both for archaeologists and for those in the applied environmental sciences. In part, the problem was a paucity of empirical data, but the problem was compounded by lack of an adequate conceptual framework within which to analyze complex relationships among multivariate phenomena.

In the interim, much has changed. The information base has been increased by an order of magnitude, and although it is still far from adequate, at least it now permits the formulation of coherent hypotheses. But, most important, systems theory has suggested a model with which to illustrate and even analyze complex interrelationships. Systems theory has had profound influences on conceptual formulations in several disciplines: in environmental science since a seminal paper by Chorley in 1962, in ecological anthropology since Geertz's *Agricultural Involution* in 1963, and in archaeology since an article by Flannery in 1968.

That a cybernetics model cannot be transferred in toto to another discipline requires little emphasis, and most of us will appreciate that systems jargon can obscure an issue as easily as illuminate it. Furthermore, it would be foolish simply to apply a biological systems approach in the social sciences. But the basic principles of systems theory are essential to integrate the environmental dimension within a contextual archaeology.

Context and ecology

Odum (1971:8) has defined an ecosystem as a community of organisms in a given area interacting with the physical environment, so that energy flow leads to clearly defined food chains, biotic diversity, and exchange of materials between the living and nonliving parts. Transforming this concept to human populations, the essential components of the noncultural environment become distance or space, topography or landforms, and resources – biotic, mineral, and atmospheric. Modern geography is particularly concerned with the interrelationships between human communities and their environments, and increasingly so with the spatial expression of the attendant socioeconomic phenomena. This focus differs only in its spatial emphasis from ecological anthropology (Hardesty, 1977; Moran, 1979), which is equally concerned with intersecting social and environmental systems.

Such broad systems concepts are, however, too complex for practical application. Yet the problem can be minimized by identifying primary research components, as distinct from ultimate systemic objectives. The primary or lower-level objectives relate to the techniques and immediate goals of each method, such as spatial archaeology, archaeometry, and environmental archaeology. The secondary or higher-level objective is the common goal of context, shared by all the contributing methods.[1]

Thus, the primary goal of environmental archaeology should be to define the characteristics and processes of the biophysical environment that provide a matrix for and interact with socioeconomic systems, as reflected, for example, in subsistence activities and settlement patterns. The secondary objective of this and of all the contributing methods is

to understand the human ecosystem defined by that systemic intersection (Chorley and Kennedy, 1971:4). A practicable general goal for contextual archaeology is the study of archaeological sites or site networks as part of a human ecosystem. It is within this human ecosystem that earlier communities interacted spatially, economically, and socially with the environmental matrices into which they were adaptively interwoven.[2] The term ecosystem, here and elsewhere in this study, is used as a conceptual framework with which to draw attention to ecosystemic interrelationships. No formal systemic structures are proposed or employed.

Less concerned with artifacts than with sites, contextual archaeology focuses on the multidimensional expression of human decision making within the environment. And, without attempting to deal directly with ecological phenomena such as energy flows and food chains, it aims to stimulate holistic research by calling attention to the complex systemic interactions among cultural, biological, and physical factors and processes.

Five central themes are singled out for specific emphasis, namely, space, scale, complexity, interaction, and stability or equilibrium state (Butzer, 1978*a*). These concepts were originally geographical or biological, but they have direct anthropological and archaeological applications, and they incorporate spatial as well as temporal dimensions. Furthermore, each of these properties is measurable and therefore replicable, and so amenable to scientific study (Butzer, 1980f).

Space. Rarely are phenomena distributed evenly in space. Topographic features, climates, biological communities, and human groups exhibit spatial patterning and thus are amenable to spatial analysis.

Scale. Spatial analysis is used to distinguish small-, medium-, and large-scale objects, aggregates, or patterns. Similarly, the configurations of living communities or physical aggregates are established,

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[1] By identifying primary and secondary goals, it is possible first to explicate how each approach contributes individually to contextual archaeology. In this way, multidisciplinary inputs can be channeled toward a common goal, obviating the need for distinct ecological and geographical paradigms, as proposed by Clarke (1972:7). Second, explicitly hierarchical goals help to identify basic research components and facilitate intermediate analysis and resolution, as well as attainment of ultimate systemic objectives.

[2] So defined, contextual archaeology includes several scales and dimensions. To clarify, scale is a metrical concept, distinct from dimension, that has both magnitude and direction, with respect to two or more coordinates, and conveys a sense of scope or perspective. Contextual archaeology implies variable scales, because both socioeconomic and spatial systems can be examined at the detailed level or the general level. It also includes several dimensions, namely, spatial (the site subsystem), hierarchical (the environmental subsystem), and ecological (the interactive processes). So, for example, this approach can be applied to simple foraging societies, in which settlement and subsistence are organized primarily on a horizontal plane, as well as complex societies characterized by significant vertical structures.

maintained, or modified by processes that operate at several spatial and temporal scales and that may be periodic or aperiodic. Microscale and macroscale studies obviously are complementary, and both are necessary for comprehensive interpretation.

Complexity. Environments and communities are not homogeneous. This makes both their characterization and delimitation difficult, thus requiring flexible, multiscale spatial and temporal approaches.

Interaction. In a complex environment with an uneven distribution of resources, human and nonhuman communities interact internally, with each other, and with the nonliving environment; they do so at different scales, from varying degrees of proximity, and at changing or unequal rates.

Equilibrium state. The diverse communities of any environmental complex are all affected to some extent by negative feedback resulting from internal processes or external inputs. In consequence, readjustment, whether minor or major, short term or long term, is the rule rather than the exception.

These five perspectives can be explicated by a number of examples that will serve to illustrate the several scales and dimensions of a contextual approach.

Scales and dimensions of contextual archaeology

A false-color LANDSAT photograph of central Illinois or eastern Africa will provide an impressive illustration of differential biotic productivity that will show how inappropriate is the basic assumption of most geometric spatial analysis – the assumption that space is homogeneous. The reds and blues show concentrated and diffuse regional patterns, some sharply demarcated, others grading across broad transitions. A census of wildlife distributions at any given moment will show similar complex aggregations.

The importance of biotic patterning in human-resource evaluation is matched by the importance of the topographic and sedimentary matrix in designing an archaeological survey or in interpreting site locations. So, for example, in the Nile Valley of Middle Egypt the known late-prehistorical sites are in no way representative of Predynastic settlement patterns, but are largely a function of selective surface preservation of only those sites on the margins of the valley (Butzer, 1960*a*). Similarly, the sites of rock engravings in southern Africa are predicated on the locations of suitable rock outcrops, microscale topographic change, and environmental variability (Butzer et al., 1979). Spatial archaeology has contributed much of value in recent years (e.g., Clarke, 1977), but many of its practitioners still do not conceptualize real space as opposed to abstract space.

The mosaic distribution of biophysical phenomena also serves to illustrate the synchronic attributes of scale. Arborescent foods can be perceived at the microscale of the individual tree or cluster of trees, at the mesoscale of individual upland or floodplain forest components, or at the macroscale of the regional forest-prairie mosaic. As a consequence, the average pollen profile may serve to establish a paleoclimatic sequence of some stratigraphic value, specific to a regional habitat or biome, but it more often than not contributes little to elucidate the complexity of a potential resource catchment, unless the palynologist approaches the problem as an archaeologist (e.g., Bryant, 1982).

This spatial perspective of scale is complemented by the temporal or diachronic framework: seasonality and predictability of collected or produced foods; the significance of cyclic anomalies, major perturbations, and long-term shifts of equilibrium thresholds that define the environmental system. Temporal variability will affect, at various scales, the biomass of plant and animal foods, and even the quantitative and qualitative characters of biotic communities. As a consequence, ecosystemic variability, trends, and transformations probably will also affect demography, subsistence strategies, settlement patterns, and even the social fabric with different degrees of intensity, depending on the magnitude of change and on the information and decisions of the human communities.

The role of complexity is readily illustrated by the parallel problems of classification and demarcation of artifact types and climatic types. What are the most appropriate criteria? Better yet, what are the practicable criteria in view of the data base? Do these describe useful classes? Are these classes mutually exclusive? The computer helps to tidy up appearances, but it does not necessarily resolve the basic logical problems of defining assemblages of artifacts and sites or the defining of biophysical phenomena. The problem is vastly compounded when one attempts to identify process and response among a chain of interlocking subsystems. The roles of possible concatenations of negative inputs can be simulated by computer, but the result will be no more than a working hypothesis. It will require multiple lines of specialized contextual investigation to identify the key components and the low or intermediate-order processual interactions.

The matter of interaction can be illustrated by the example of Axum, an early civilization that flourished in northern Ethiopia during the first millennium A.D. (Butzer, 1981*a*). Axum owed its prosperity to international trade, but its market resources were found in several distinct environments occupied by alien peoples bound in various relationships to Axum. Gold came from the semiarid lowlands that Axum temporarily dominated but never fully controlled. Ivory and frankincense were initially abundant in local upland forests, but as both elephants and trees became increasingly scarce, ivory had to be obtained from distant parts of humid Ethiopia. In fact, the demographic base of Axum eventually exceeded the subsistence productivity of its local habitat. When international market demand faltered during the seventh century, Axum lost the means to control its critical trade resources. Because it lacked an adequate subsistence base in isolation, excessive demographic pressure led to severe landscape degradation and general impoverishment. Concomitantly, repeated failure of the spring rains meant one rather than two annual crops on unirrigated lands. Drastic depopulation ensued. Eventually there was a shift of power and population to new and more productive environments in central Ethiopia. Axum provides an example of how spatial and temporal availability of resources, and the interactions between a society and its resource base, can be of fundamental significance in the analysis of historical processes.

In the larger perspective, it is apparent that elaborate prehistorical and historical cultural systems have enjoyed centuries of adaptive equilibrium, with or without sustained growth, that have then been followed by discontinuities. The five millennia of Egyptian history (Butzer, 1981*b*) and Mesopotamian history (Adams, 1978) show cyclic alternations between centuries when population and productivity increased in apparent response to effective hierarchical control and other centuries marked by demographic decline and political fragmentation. Endogenic and exogenic inputs led to repeated readjustments. Whereas minor crises were overcome by temporary structural shifts, major crises required reorganization of the political and economic superstructure, with or without a transformation of identity. But the fundamental adaptive system continues to survive in Egypt and modern Iraq as a flexible but persistent social adjustment to a floodplain environment. In the long-range view, elaborate cultural systems are dynamic rather than stable or homeostatic, because structural changes are repeatedly required to ensure viability and even survival (Butzer, 1980*c*).

A unifying thread in these illustrations of the hierarchical components of a contextual paradigm is provided by *adaptation* (specifically as a strategy for survival) and *adaptability* (as the capacity of a cultural system to adjust) (see Chapter 15). These concepts, as defined in cultural terms rather than biological terms (Kirch, 1980*a*), are at the heart of the human ecosystem; they provide criteria for the analysis of historical process and culture change that I believe to be more suitable than those of the popular ontogenetic model that compares civilizations and cultures with organisms that first grow and then die. Archaeologists share with cultural anthropologists, historians, and students of human geography the ultimate objective of historical interpretation. Many conceptual methods and models are also shared. But the analytical techniques and scientific methods of the archaeologist have less in common with the techniques and methods in these other fields. This point can be demonstrated by drawing attention to the literature on natural extremes and social resilience: Central in all instances are the roles of the individual and of the community in decision making (Burton et al., 1978; Torry, 1979). In default of any historical records or a reasonable degree of ethnographic continuity, prehistorical archaeology can never hope to elucidate the nature of this decision-making process. We may or may not be able to identify the outcome of such a process, but we shall never know why, how, or when it was initiated.

Archaeology as archaeology

It has been said that archaeology is anthropology or it is nothing (Willey and Phillips, 1958:2). I beg to differ with this view. Archaeology and cultural anthropology do, or at least should, enjoy a close symbiotic relationship, and archaeology is indeed critically dependent on stimuli and models grounded in social, ecological, and evolutionary anthropology. But archaeology has been equally dependent on geology, biology, and geography at various times during its development. Archaeology is a complex social science in its own right – a view recently articulated by Gumerman and Phillips (1978) as well as Wiseman (1980). But, like geography, archaeology is heavily dependent on both the empirical methods and models of the natural sciences, qualifying as a social science mainly by virtue of its objectives. The specific methodologies of other disciplines, including cultural anthropology and biology, cannot simply be transferred; they must be transformed, according to a new paradigm rather than a secondary paradigm, if they are to have productive input. For this reason, I feel as uncomfortable with an unadapted cultural anthropological paradigm as with a biological one. Context represents a traditional concern of archaeology,[3] and, as more comprehensively defined here, it is developed with conceptual input from cultural anthropology, human geography, and biological ecology.

I am therefore arguing for a contextual archaeology rather than an anthropological archaeology. My plea is for deliberate exploration and development of an approach that will transcend the traditional preoccupation with artifacts and with sites in isolation, to arrive at a realistic appreciation of the environmental matrix and of its potential spatial, economic, and social interactions with the subsistence-settlement system. The human ecosystem so defined will open up truly ecological vistas that have been largely neglected. This contextual approach, heavily dependent on archaeobotany, zoo-archaeology, geo-archaeology, and spatial archaeology, is new not in terms of its components but by virtue of its integrated, general goal of understanding the human ecosystem. The key to this systemic approach is the set of perspectives described earlier: space, scale, complexity, interaction, and stability. Contextual archaeology complements the traditional concern for analysis and socioeconomic interpretation of artifacts and artifactual patterns by providing new spatial, hierarchical, and ecological dimensions. It is a matter of some urgency that this dynamic perspective be developed and implemented in both college education and field or salvage projects, because it is indispensable for our comprehension of human ecosystems.

It can be argued that traditional social and economic interests in the variability of technology and style are subsumed in an overarching contextual paradigm that seeks to explain multigenerational stability in various systemic interrelationships between peoples and their environments (Schoenwetter, 1981). Heuristically, however, it is preferable to concentrate on those approaches and themes singled out as central to contextual archaeology. No one paradigm deserves to be enshrined as superlative; alternative viewpoints are essential to good scientific practice. By systematically developing the methodology of an alternative (rather than exclusive) paradigm, and then applying it to the fundamental issues of adaptation, stability, and change, it will be possible for students and professionals to appreciate the procedural potentials and to evaluate the merits of a contextual approach.

The subsequent chapters of this book develop these perspectives, beginning with an introduction to the spatial and temporal variability of environmental systems. Then the methodologies of the individual subfields (geo-archaeology, archaeometry, archaeobotany, and zoo-archaeology) are introduced, providing study components to examine the interaction spheres between prehistorical peoples and their biophysical environments. This discussion goes beyond ecological interpretation of sites and their containing landscapes to consider the impact of settlement on site formation and the impact of subsistence activities on plants, animals, soils, and overall landscape modification. Finally, the integrated contributions of contextual archaeology are applied to a spatial analysis of settlement patterning and to a temporal examination of cultural continuity and change.

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[3] Differing concepts of context have been applied by Taylor (1948, 1972), Helm (1962), and Schiffer (1972).

CHAPTER 2

Environmental systems: spatial and temporal variability

Space and scale in ecology

The practical and theoretical issues of environment and context in archaeology require a familiarity with environmental systems. These provide both the spatial and temporal frameworks, physical and biotic, within which human communities interact and that, equally so, interact with human communities.

The *biosphere* encompasses all of the earth's living organisms, interacting with the physical environment in an infinite number of component systems. For practical reasons, biologists commonly select only a part of the biosphere for direct study, and they may focus on vertical (hierarchical) or horizontal (spatial) interactions.

Levels of vertical organization begin with genes and cells and then range upward successively to organisms, populations, and communities. The population comprises groups of individuals of any one kind of organism, whereas the community includes all of the populations occupying a given area (Odum, 1971:4–5). Finally, the community and the nonliving environment function together in an ecosystem. Study may concentrate on an individual organism or a single population (autecology), or on a community (synecology). Such communities may be large or small, with a corresponding difference in the degree of dependence on inputs from adjacent communities. The communities, and the ecosystems they imply, range in dimension from local to subcontinental in scale.

In terms of horizontal organization, the largest terrestrial communities define the earth's key biotic landscapes. These are *biomes*, described as "major regions in which distinctive plant and animal groups usually live in harmony with each other, so that one may make tentative, but meaningful, correlations between all three" (Watts, 1971:186).

A biome includes an unlimited number of partly overlapping *habitats*, representing the space in which different populations or communities

live. The spatial transition between two or more different communities represents the *ecotone*, a tension belt that is narrower than the habitats of adjoining communities but that may have considerable linear extent (Odum, 1971:157). A particular locale within a habitat, together with its immediate setting, is a *site*. Finally, biotic and abiotic spatial aggregates can be contrasted as biochores and physiochores (Schmidthüsen, 1968:78). The biochore is the area occupied by one or more communities, such as the range of a single population, a plant "formation" or animal "zone" that includes several communities, or an overarching biotic province. A physiochore is a particular area defined by a set of physical parameters along the intersection of atmosphere and lithosphere. Biomes or their multiple-component habitats all have spatial, biotic, and abiotic dimensions and therefore comprise both a biochore and a physiochore that are spatially coincident.

Ecology emphasizes functional relationships rather than phyletic or genetic relationships. This is effectively illustrated in the concept of *niche*. Odum compared habitat with the address of an organism and niche with the occupation of the organism. Explicitly, niche includes the physical space occupied by the organism, its functional role in the community, and how it is constrained by other species and abiotic factors (Odum, 1971:234). Central to the maintenance of an ecosystem is the regulation of trophic levels (i.e., vertical food chains) and patterns of energy flow (Figure 2-1). Consequently, biomes, as major world ecosystems, maintain a functional unity across space by virtue of communities that have similar functions, whether or not species composition remains the same. So, for example, the species and even the genera of dominant trees and animals within the circumpolar needle-leaved forest are different from region to region across the Northern Hemisphere's boreal zone. Thus species are, to a large extent, replaceable in space as well as in time (Odum, 1971:140).

Biomes as environmental systems

The ecological concepts discussed in the preceding section are central to environmental analysis, because a biome is equivalent to a macroenvironment. Such large-scale environments are normally delimited on the global maps found in textbooks on biology and geography. They also, on occasion, are linked to "culture areas" in which human communities are believed to have similar material cultures (Kroeber, 1939; Carter, 1975). Although these divisions generally are too coarse to

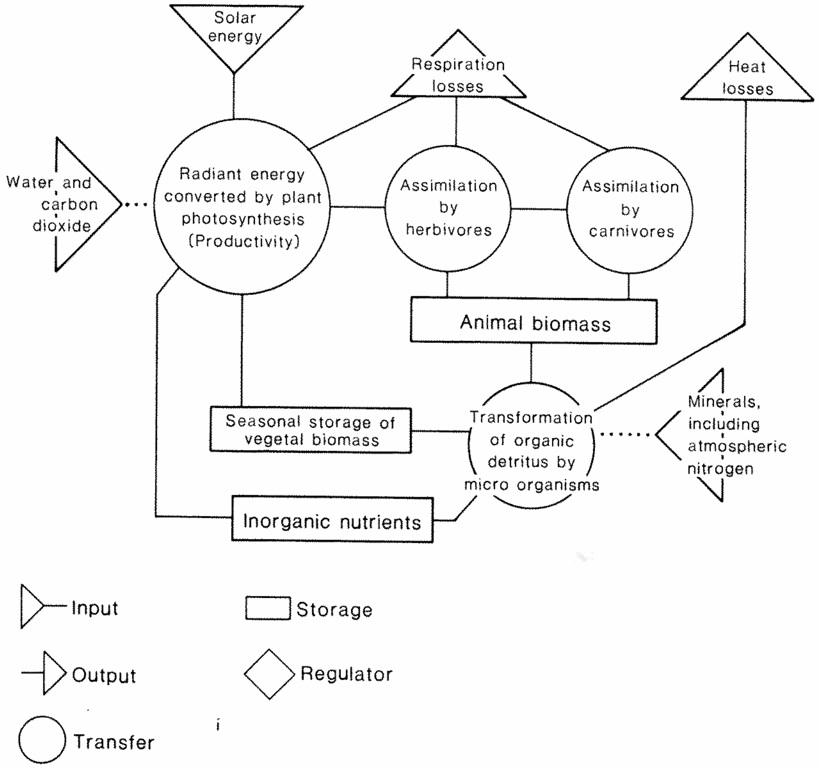

Figure 2-1. Simplified energy cycle for an environmental system. The symbols used in Figures 2-1, 2-2, and 2-6 follow those of Chorley and Kennedy (1971).

serve as a useful frame of reference for subsistence potentials, they are convenient for discussion of the key environmental variables and their modes of interaction.

The four basic components of an environmental system are atmosphere, hydrosphere, lithosphere, and biosphere (Figure 2-1). The critical variables within these major categories are outlined in Table 2-1 in the format of a checklist. Enumeration of these variables is primarily of heuristic value, because the raw data in any one subcategory are difficult to abstract into a form useful to explicate systemic interactions. For example, synthetic expression of climatic types can be achieved only by the use of costly computer programs. Even then the variables require simplification, both in terms of computer time and in terms of the limited amount of empirical data for elements such as evaporation or wind speed and direction. This problem has bedeviled climatology for almost a century, as exemplified by the countless simplified classifications devised to illustrate the organization and distribution of climates on the continents. Even when climatic regions are identified as fitting

Table 2-1. *Key variables of an environmental system*

Atmosphere (Crowe, 1979)

Macroclimate, including radiation patterns and thermal distributions; evaporation, water vapor, and precipitation; atmospheric pressure and winds; seasonality and aperiodic variations of these elements

Microclimate, small-scale deviations from modal climate resulting from variable exposure to climatic elements (e.g., shade versus sun slopes) and topographic contrasts that affect low-level air currents; other local climates of the soil, of forests, of cities, etc.

Hydrosphere (Chorley, 1969)

Oceans and seas, with saltwater shores modified by wave activity and local river influx and partly influenced by tidal variation

Freshwater lakes, partly modified by wave action or stream input

Streams, permanent or temporary, dominated by channeled flow, as well as other land surfaces, directly modeled by diffuse runoff.

Soil water and groundwater, particularly capillary and gravitational moisture capable of vertical and lateral movement, ion transfer, and rock alteration

Ice, including freeze–thaw cycles in soil and rock, permanently frozen subsoil, temporary snow mantles, and glaciers

Lithosphere (Butzer, 1976*a*)

Rocks and structures, providing minerals that are eroded, transported, and deposited in materials cycles and that affect permeability and porosity and the nature of potential mineral nutrients, as well as local transformations such as vulcanism, earthquakes, and landslides

Terrain, including elevation, roughness, spacings of valleys and mountains, and inclinations and lengths of slopes; controls dominant geomorphic processes, potential energy, rates of change, and local probability of flooding or soil waterlogging

Soils, differing from intact bedrock in texture, nutrient types, organic content, and microorganic activity.

Biosphere (Odum, 1971)

Organic compounds, including proteins, carbohydrates, and humus.

Plants, mainly photosynthetic organisms that incorporate inorganic substances and water

Animals, including primary consumers of organic matter (herbivores) and secondary consumers of other organisms (carnivores)

Microorganisms, such as earthworms, soil insects, bacteria, and fungi that transform organic detritus, providing energy and stimulating or inhibiting other biotic components

Biomass and primary productivity, determining community energetics in relation to species diversity, population levels, food chains, community respiration, and storage

Nutrient cycling, including mineral cycles, nutrient exchange rates between organisms and environment, and nutrient regeneration from organic detritus by microorganisms specific biochores, the emphasis on delimitation is unfortunate, if for no other reason than that biotic and physiographic boundaries are arbitrary abstractions that cut across complex transition belts.

The terrestrial segment of the hydrosphere is somewhat elusive to deal with, because horizontal boundaries often are ephemeral, and parts of the hydrosphere either are in constant interchange with the atmosphere or are internetworked with the lithosphere. Similarly, the soil mantle, as the most important single element of the lithosphere, is commonly interdigitated with the biosphere in terms of microorganism activity and nutrient cycling. Classification is further impeded by innate taxonomic problems and by the fact that land surfaces differ greatly in terms of age and environmental history.

Finally, biotic distributions are difficult to characterize, because genetic, historical, and ecological criteria all require attention. Vegetation, for example, can be described in terms of floristics (genera and species), physiognomy (based on leaf shape and seasonality, as well as height and spacing of the largest plants), or formations (which link dominant species and physiognomic properties). But even a physiognomic or formational approach aimed at ecological synthesis is complicated by the historical trajectory (e.g., plant migration and local isolation or extermination). In the case of animal zonation, species ranges are largely determined by physical barriers, dispersal patterns, and paleoclimatic history, whereas the animals themselves often have become adapted, in the form of local ecotypes, through physiological acclimatization or minor genetic divergence (see Chapter 11). Even in isolating biotic communities with a degree of functional unity, the mobility, seasonality, and limited specialization of many larger mammals and birds make boundary definition highly arbitrary.

Thus there is no ready procedure to define and apply the ecosystemic variables that characterize world biomes. The problem is compounded in attempting to describe, let alone operationalize, the interactions. Three examples of interaction can be profitably discussed here.

The interrelationships among vegetation, soil, and lithosphere are most obvious in patchy (i.e., *mosaic*) distributions. Areas with poor topographic drainage, low-nutrient parent material, or bedrock with unusual permeability or mineralogy favor deviations in soil and vegetation types from the regional norm. Such *edaphic* factors (see Chapter 4) are responsible for tundra islands within the subarctic boreal forests, grassland patches amid tropical woodlands, and riverbank gallery forests in desert or grassy environments.

The systemic role of biotic communities interacting with the physical environment is best exemplified by energy flows and energy balances (i.e., energetics). Useful components for reference are *biomass*, the living weight of all plants and animals, and *primary productivity*, the rate at which plant matter is produced by photosynthesis (Figure 2-1). However, in detail, the relevant equations are complex and can be resolved only for simplified biotic or cultural subsystems (e.g., Rappaport, 1971*a*; Nietschmann, 1972). Population dynamics and interpopulation relationships are critical to a broader appreciation of energetics within the complex hierarchy of communities in the food chain. Furthermore, a single time slice cannot accommodate the normal and anomalous variabilities in energy flows effected by cyclic oscillations among several components within each trophic level. Despite such practical limitations, the usefulness of the energetics approach in ecological anthropology has been demonstrated by Hardesty (1977).

The interactions among all four major environmental realms are most dramatically illustrated by the geomorphic activities of running water, waves, ice, gravity, and wind. For example, radiation energy evaporates water from the ocean; it is carried as water vapor by winds onto land, where it is dropped as rain, to become diffuse surface runoff and river discharge; after eroding an increment of the soil cover and performing local channel modification, the water returns to a lake or sea, where it may first play a role in delta extension and subsequently in wave action. In the meantime, moisture added to rock interstices permits chemical weathering, and free soil water transfers mineral nutrients within the soil profile or flushes them out into the rivers, where, together with inert mineral sediment, they sweep downstream as solutes and suspended clay or silt, with sand and gravel jumping or rolling along the channel as bed load. The broadly defined roles of geomorphic processes on the land surface, within the soil, and along the interface of land and water are expressed in the concept of mineral cycles. These processes determine the stability of the soil mantle and the physical transformation of the lithosphere, and therefore they are the most tangible of the various materials cycles in an ecosystem (Figure 2-2).

The complexities of even the rudimentary and partial systems sketched here serve to show that modern functional ecosystems are essentially impractical for empirical study. Not surprisingly, past systems remain beyond reconstruction. However, for most ecologists the ecosystem serves primarily as a paradigm, a broad conceptual

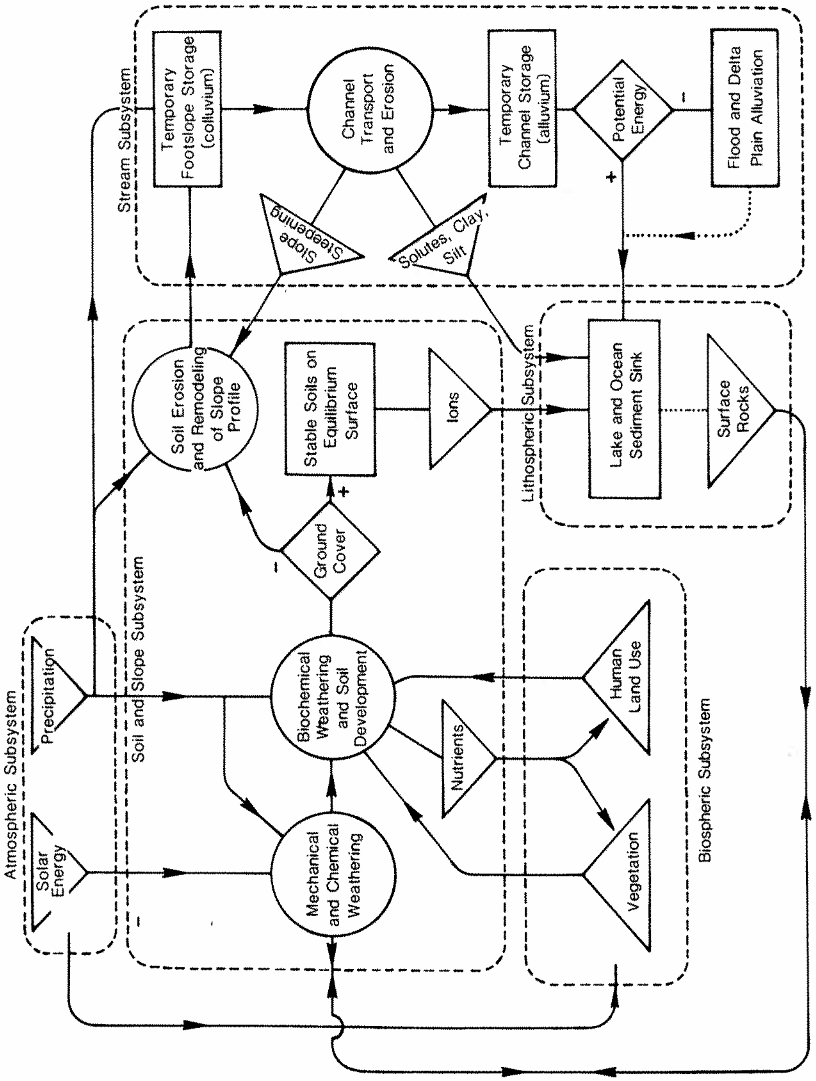

Figure 2-2. A simplified mineral cycle involving weathering, soils, and running water. Vegetation type, human interference, and climatic change can affect the critical ground-cover "regulator." Changes in climate, sea level, and tectonic input can affect the potential energy (available relief).

approach within which to organize and interpret data. The environmental system has a similar focal and heuristic value in contextual archaeology. Specifically, energy and mineral flows highlight two of the most significant spheres of interaction among the components of the environmental system in general and of the human ecosystem in particular.

Equilibrium properties

Like other interactive networks, environmental systems comprise integrated feedback subsystems that operate in a self-regulatory manner and enrich the system by providing it with greater flexibility (Chorley and Kennedy, 1971). *Feedback* is a systemic property whereby change, as introduced by one of the variables, is transmitted through the whole structure, back to the initial variable. Negative feedback sets up a closed loop of change that dampens or stabilizes the effect of the original change, maintaining a *stable equilibirum* or a *dynamic equilibrium* (Figure 2-3). Positive feedback reinforces the effect of the externally induced changes, accelerating changes in the direction of the initial action. Eventually, limits are provided by individual variables that cannot operate indefinitely in one direction.

The atmosphere provides good examples of both types of feedback. Despite repeated anomalies, such as cold winters, wet summers, and severe storms, the basic atmospheric controls set constraints to each aberration until this negative feedback induces a return to a "normal" mode of behavior. Long-term climatic changes involve a concatenation of events. For example, a decrease in temperature increases the amount of snowfall, prolonging the snow-cover season and increasing the reflectivity of the earth's surface (albedo), thus reinforcing the cold. If these positive-feedback mechanisms prevail long enough, the atmospheric circulation may settle into a new, adjusted modal behavior that will once again be maintained by negative feedback.

Natural systems are characterized mainly by negative-feedback propensities, so that changes in the energy environment will favor readjustment of the system variables into an oscillating pattern, called *steady state* (Figure 2-3). Such self-regulatory change is called *dynamic homeostasis* (Chorley and Kennedy, 1971:15). Self-regulation is complicated by two factors: (a) *secondary responses*, which occur when one or more changes continue to operate after the initial energy change has been reversed (e.g., valleyside gullying may begin in response to a temporary environmental condition, but headward channel erosion,

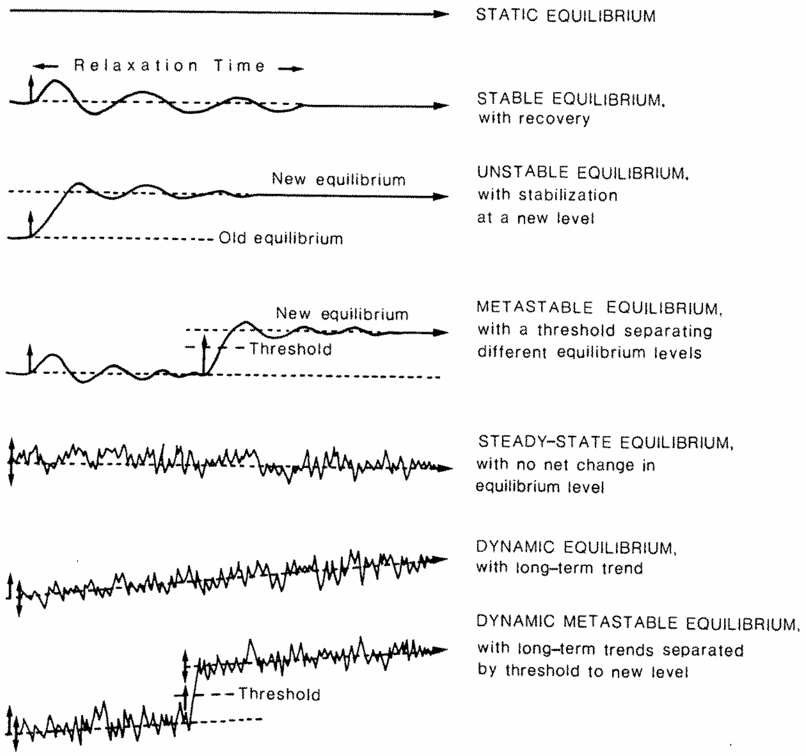

Figure 2-3. Equilibrium types. The vertical arrows indicate changes in the controlling variables. Modified from Chorley and Kennedy (1971:Figure 6.1).

once started, will commonly continue); (b) *thresholds*, which are reached when a small change in one critical variable forces the system into a radically different dynamic equilibrium, often irreversibly so (Chorley and Kennedy, 1971:237). Systems prone to such drastic transformations are *metastable* (Figure 2-3).

The time that elapses between the onset of a perturbation and the reestablishment of the steady state is the *relaxation time* (Chorley and Kennedy, 1971:15), which provides a measure of the elasticity of the system (Orians, 1975). The ability of the system to resist external perturbations and to respond to inputs without crossing a threshold is called inertia or *resilience* (Holling, 1973; Orians, 1975).

Much of the cyclical stability of environmental systems is related to seasonality, so that it is useful to distinguish constancy, in which the state is the same for all seasons in all years, from contingency, in which the state is different for each season but the pattern is the same for all years (Colwell, 1974). For example, landforms, the oceans, and many deep-seated thermal springs exhibit complete constancy, whereas most biota are noted for various degrees of contingency. Together, constancy and contingency define *predictability* (Colwell, 1974), a concept useful for measuring variations in periodic phenomena. For example, rainfall is most predictable in equatorial rain forests because of its high constancy. It is also relatively predictable in the Mediterranean Basin woodlands, with their marked summer drought, because the winter rainfall patterns provide a high level of contingency.

When perturbations are primarily random or *stochastic* in character, predictions regarding system behavior can be made in probability terms. *Probabilistic* patterning contrasts with *deterministic* occurrences, where behavior is mathematically predictable. Random departures from predictable regularity represent *noise*. Finally, there may be *statistical* regularity when random events become predictable as a group, evaluated in the context of longer time series. Examples are provided by the statistical frequencies of peak floods that spill over a river's banks or that inundate an entire floodplain.

Scales of environmental variability

Variability is a central aspect of context. The scales or orders of environmental fluctuations or change can best be gauged from the empirical record, as outlined in Table 2-2.

The wavelengths of environmental variations range from a few years to several million years. There is a proportional relationship whereby longer-term changes tend to have greater amplitudes and more universal effects. But closer inspection shows many exceptions. Some of these dimensions can be illustrated by the western coast of North America (Wolfe, 1978). Here the early Tertiary period had an annual temperature range, between the warmest and coldest months, of 5°C. During the late Tertiary the annual range increased to 17°C to 27°C. Tertiary climatic fluctuations had a wavelength of 9 to 10 million years, with an amplitude of 7°C during the early Tertiary and 2°C to 4°C during the late Tertiary. During the Pleistocene ice age, the last 2 million years, wavelengths were drastically shortened, averaging just under 100,000 years, with an amplitude of 10°C to 20°C. On a planetary scale, the

Table 2-2. *Scales of climatic variation*

First order (less than 10 years): year-to-year oscillations, including the 26-month atmospheric "pulse," the Great Plains dust bowl of 1934–9, and the Sahel drought of 1971–4

Second order (several decades):[a] short-term anomalies, such as well-defined trends in the instrumental record, including the Arctic warmup of A.D. 1900–40 and the dry spell in East Africa A.D. 1900–60

Third order (several centuries):[b] long-term anomalies, such as the worldwide "little ice age" of about A.D. 1400–1900 or the warm European "little optimum" of A.D. 1000–1200, of sufficient amplitude to show up in geological records; third-order climatic variations include repeated oscillations during the 10,000 years of the Holocene

Fourth order (several millennia):[c] major perturbations, such as severe interruptions within the last interglacial, the stadial-interstadial oscillations of the last glacial, and the warm and often drier millennia between 8,000 and 5,000 years ago (Altithermal, Climatic Optimum)

Fifth order (several tens of millennia):[d] major climatic cycles of the order of magnitude of glacials and interglacials, spanning 20,000 to 70,000 years, with eight glacials verified during the last 700,000 years

Sixth order (several million years):[e] geological eras, including the durations of ice ages such as the Permocarboniferous (ca. 10–20 million years long, about 290 million years ago) and Pleistocene (formally began 1.8 million years ago, with major cooling evident for 3.5 million years)

[a] Fritts et al. (1979); Lamb (1977); Butzer (1971*b*).
[b] Ladurie (1971); Grove (1979).
[c] Kukla (1975); Woillard (1978); Flohn (1979).
[d] Kukla (1975); Butzer (1974*b*).
[e] Wolfe (1978); Crowell and Frakes (1970).

contrasting environmental zonations between early Tertiary, Pleistocene glacial, and modern patterns are shown in Figure 2-4.

The fifth- and sixth-order changes of geological time are of obvious interest to mammalian and primate evolution, but adaptive responses are more likely to take place in relation to lower-order variability. The wavelengths of some empirically determined third- to fifth-order changes are compiled in Table 2-3. Perturbations are identified with the smallest units of resolution in the geological record, regardless of amplitude. Biome shifts can be identified on the basis of pollen records, soil-forming trends, and lake cycles. Typical perturbations last 1 to 3 millennia, whereas the identified biome shifts suggest two modal classes with 5 to 7 millennia and 12 to 50 millennia persistence. Repeated long-term periodicities may exist, but they have not yet been demonstrated for regions of continental magnitude.

Of particular interest are the long, detailed records of pollen, sediment, and oxygen isotopic changes (Johnsen et al., 1972; Kukla, 1975; Woillard, 1978). These exhibit several distinct patterns during the course of interglacials and glacials. The warmest episodes of the last interglacial period and Holocene period were marked by steady-state or dynamic equilibria, interrupted by several perturbations, each with a recovery time of 1 to 3 millennia (Figure 2-5). The switches from interglacial to glacial and back again are examples of a dynamic, metastable equilibrium, with critical thresholds crossed 70,000 years ago at the beginning of the last glacial period and again 10,500 years ago at the end of the last glacial. Particularly striking are the severe perturbations during the transition from last interglacial to last glacial, suggesting a complex interplay of negative feedback and positive feedback. The last glacial-to-Holocene transition, on the other hand, was remarkably abrupt in some kinds of records, but marked by a single violent oscillation in others. Also of interest is the high amplitude of cyclic changes throughout the last glacial, with repeated perturbations at several scales. This suggests that glacials represent inherently less stable circulation modes of the atmosphere, repeatedly counteracted by potent negative-feedback mechanisms.

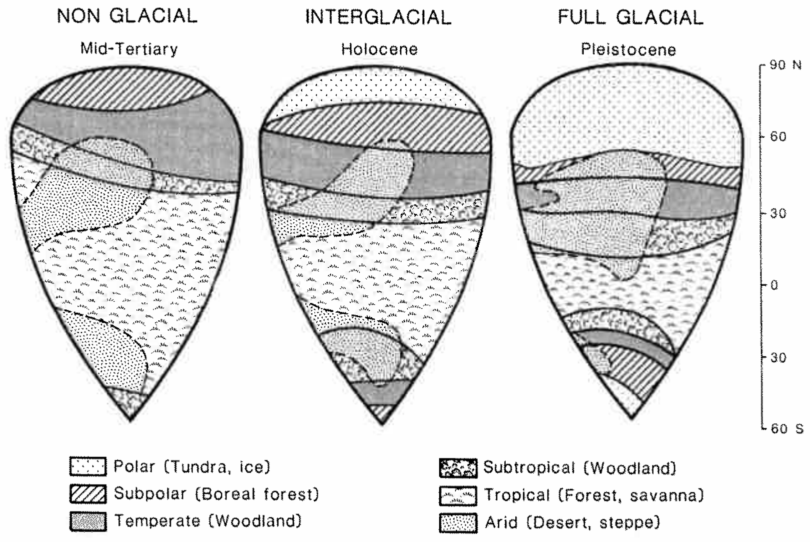

Figure 2-4. Models for planetary biotic zonation during mid-Tertiary nonglacial conditions, during the present interglacial, and during a Pleistocene full glacial. The idealized continent represents the composite land mass in each latitudinal belt. Modified from Butzer (1976*b*: Figure 16-2).

The process-and response system of the earth's atmosphere remains

Table 2-3. *Wavelengths of perturbations and biome shifts in the recent geological record (in millennia)*

Region and perturbation	Range	Modal value	Biome shift	Control period
France (pollen)[a]	0.3–2.0	0.7–2	5–50	140
Central Europe (rivers)[b]	0.2–3.0	2		10
Czechoslovakia (loess)[c]	1.0–10	2–5	5–25	125
Illinois (loess)[d]	0.5–2.5	0.7–2	5–12	30
Mediterranean (vegetation)[e]	1.25–12.5	2–10	5–50	125
Mediterranean (streams)[b]	1.25–7.5	2–5		10
Egyptian desert (streams)[f]	0.1–4.0	1.5–3		30
Tibesti, central Sahara (streams)[g]	0.15–3.0	0.4–2.5	8	30
Chad Basin (lake levels)[h]	0.1–12	0.15–2	8–12	30
Upper Nile Basin (discharge)[f]	0.25–3.5	0.8–2	7–12	30
Rudolf Basin (lake levels)[i]	0.2–2.0	0.5–1	7.5–20	40
Vaal-Orange Basin (streams, springs)[j]	0.4–4.5	0.6–4	4–12	30
Southern Cape, S. Africa (soils, vegetation)[k]	1.0–10	1–3	5–20	40
Antarctica, Greenland (ice cores)[l]	0.18–6.0	0.4–3	3–50[m]	125
Median	0.5–5.9	1.1–3.3	5–24	

[a] Woillard (1978). [b] Butzer (1980*a*). [c] Kukla (1975).
[d] Butzer (1977*a*). [e] Florschütz et al. (1971). [f] Butzer (1979).
[g] Jäkel (1979). [h] Maley (1977); Servant (1973). [i] Butzer (1980*b*).
[j] Butzer (1978*b*); Butzer, Stuckenrath, et al. (1978).
[k] Butzer and Helgren (1972); Schalke (1973).
[l] Johnsen et al. (1972).
[m] Duration of major oxygen isotope deviations in solid precipitation.

poorly understood. It is evident that plate tectonics have influenced sixth-order trends by shifting continental locations and creating mountain ranges in critical areas. It is also apparent that variations in the earth's orbital parameters (speed of spin, inclination and wobble of axis, asymmetry of orbit) have influenced the spacing of fifth-order climatic changes. But inputs from solar variability (small- and larger-scale emissions), volcanic dust in the atmosphere, reversals and changes in the geomagnetic field, as well other factors, are also very probable. The brief and remarkably severe fourth-order variations remain unaccounted for; yet they were evidently critical in triggering or modifying fifth-order changes. In sum, climatic change is a response to multivariate factors that are part of a system for which we barely know the variables, let alone their quantitative potentials.

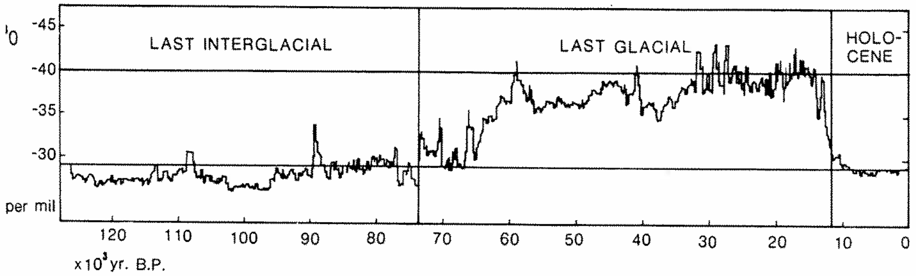

Figure 2-5. Climatic changes during the last 125,000 years as indicated by changes in the oxygen isotope composition of the Greenland ice sheet. The temporal scale is slightly distorted. Modified from Johnsen et al. (1972).

Of significance to contextual archaeology is that climatic changes of several wavelengths and amplitudes have repeatedly punctuated the prehistorical past. Statistical stability of sorts have prevailed for some spans of up to several millennia, but the superimposed first-, second-, and third-order variations, for example, have had significant impact on biomass in many environments. The repeated perturbations in many instances resulted from a primary input of only a few centuries, perhaps as little as 50 years (Flohn, 1979), whereas the subsequent recovery time extended over a few millennia. Many fourth-order and most fifth-order variations were associated with wholesale transformations of biomes. Altogether, this is a fascinating field for further exploration.

Models for ecosystemic change

The empirical evidence assembled in the preceding section illustrates several possible equilibrium patterns inherent to major natural ecosystems: (a) steady-state equilibrium, (b) dynamic equilibrium, (c) dynamic equilibrium punctuated by major perturbations, followed by recovery, and (d) dynamic metastable equilibrium, with long-term crossing of a threshold. These patterns can be linked to different scales of variability. They also display a generalized interrelationship between wavelength and amplitude, and they affect physical and biological components dif-

Table 2-4. *Models for scale changes in ecosystems*

Small-scale variability (first and second order)	Medium-scale variability (third and fourth order)	Large-scale variability (fourth and fifth order)
Year-to-year anomalies, or cyclic variations, up to several decades Steady-state or dynamic equilibrium Fluctuations in seasonal availability or aperiodic availability of water, primary productivity, and biomass of plant foods Affects resource levels for macroconsumers and animal biomass; impact greatest in biomes with low predictability No change in stream behavior or biochore definition	Dynamic equilibrium, with major perturbations or low-threshold equilibrium shifts lasting a few centuries or millennia Fundamental changes in hydrology, productivity, and all categories of biomass Shifts in soil-slope balance favor readjustments of stream behavior, with downcutting or alluviation, tangible in geological record Qualitative composition of biotic communities persists, but quantitative changes affect mosaic structures in general and ecotones in particular (e.g., species number and selected population densities); minor changes in biochore definition	High-threshold, metastable equilibrium changes, with biome shifts during course of several centuries but persisting for millennia, even tens of millennia Hydrological and geomorphic systems include new components, creating different soil and sediment assemblages New ranking of dominants and subdominants in biotic communities, with transformation in biome physiognomy and biochore definition Geological and biotic discontinuities provide stratigraphic markers tangible over continental areas

ferently. The nature of three orders of variability is outlined in the models presented in Table 2-4.

The variable wavelengths of environmental variation that are documented in Table 2-3 provide examples that suggest general patterns at several scales. However, a simplified data scheme of this type glosses over fundamental differences among the physical and biotic components of ecosystems.

This point can be illustrated by the central European geomorphic record, which shows that relatively brief climatic anomalies of a few centuries duration had significant hydrological impact (Butzer, 1980*a*). Hydrology is a complex subject that must take account of the ratios of precipitation runoff to (a) soil infiltration, (b) periodic concentrations of stream discharge, and (c) the amplitudes and recurrence intervals of peak floods. Such changes affect the balance of soil development and soil erosion on slopes everywhere by modifying soil microclimates, the completeness of soil binding and rainsplash-retarding ground cover, and the amount and speed of surface runoff, as well as topsoil stripping, slumping, or gullying. In turn, the stream network responds both to runoff concentration (brief accentuated flood crests or protracted but less violent high-water surges) and to slope sediment supply (great or small). The net result is that streams may begin either to straighten and deepen their channels (downcutting), or to increase their sinuosity or branching tendencies, favoring net sediment accumulation (alluviation) (Figure 2-2).

Cycles of downcutting, followed by renewed alluviation, can be verified in the central European record at intervals of several centuries to several millennia. Some younger gullying cycles can be linked to human interference, but most were in response to climatic impulses. The responsible third-order anomalies are only partly visible in the pollen record (possibly as a result of coarse sampling increments), although such changes are more apparent in tree-ring records (Becker and Frenzel, 1977). This argues that the slope-soil-stream subsystems had lower critical thresholds than did the vegetative subsystems in humid central Europe. Striking changes in the pollen record are evident only at the fourth-, fifth-, and sixth-order levels, that is, shifts between the standard "postglacial" pollen zones (Butzer, 1971*a*:530–3), or internal transformation of biomes during the course of the last interglacial (Kukla, 1975), or even total replacement of woodland and parkland by tundra-steppe at the beginning of the last glacial (Frenzel, 1968). The fifth- and sixth-order changes not only helped trigger downcutting-and-alluviation cycles but also introduced new slope processes, such as frost-assisted gravity movements and windborne dust (loess), while fundamentally changing stream sediments from predominantly suspended clay and silt to predominantly sand or even gravelly bed loads (Butzer, 1971*a*:Chapter 18; Kukla, 1975).

Thus ecosystems are characterized by different subsystems that have distinct thresholds, and individual subsystems have several potential thresholds in response to changes of different orders. From the data sources of Table 2-3 it appears that the hydrology and fluvial subsystems, in general, tend to be most sensitive to environmental inputs, whereas physiognomic plant formations and mammalian communities (as presently sampled) appear to be least sensitive; the soil-slope subsystem and the biotic components of complex communities or biomes appear to have intermediate responses. It seems ironic that landform constellations, the more durable of environmental phenomena, are in the long term governed by processual subsystems that provide some of the most discriminating records of detailed, small-scale changes. This explains the almost unlimited potential of geo-archaeological research in contextual analysis.

Another basic inference can be drawn from Table 2-3. Inertia varies from one biome to another. Woodland environments of high predictability, such as those of western Europe and the Mediterranean Basin, have experienced the greatest biome resilience. Middle-latitude parklands along the humid-semiarid ecotones of the American Midwest and east-central Europe are prone to greater variability, both seasonal and annual, and exhibit lower inertia in the geological record. Hyperarid deserts, such as the Sahara, are highly predictable, and biome shifts in the recent geological past have affected only the mountains (e.g., the Tibesti) and the desert margins. The semiarid tropical and subtropical environments of Africa have had low predictability and limited inertia. Finally, the greatest stability of all is evident in the ocean-atmospheric subsystem that feeds the ice sheets of Greenland and Antarctica, glaciers that have persisted for at least 3 million years.

The dynamics of environmental systems can be understood only in light of historical investigation, that is, from a *diachronic* perspective that focuses on temporal process and effect and so transcends the limitations of a contemporary approach. Like all perspectives, the *synchronic* is a simplified model of reality, because processual change is "frozen" in order to explicate the components, form, and interactions of a system. These approaches are complementary, a point unfortu-

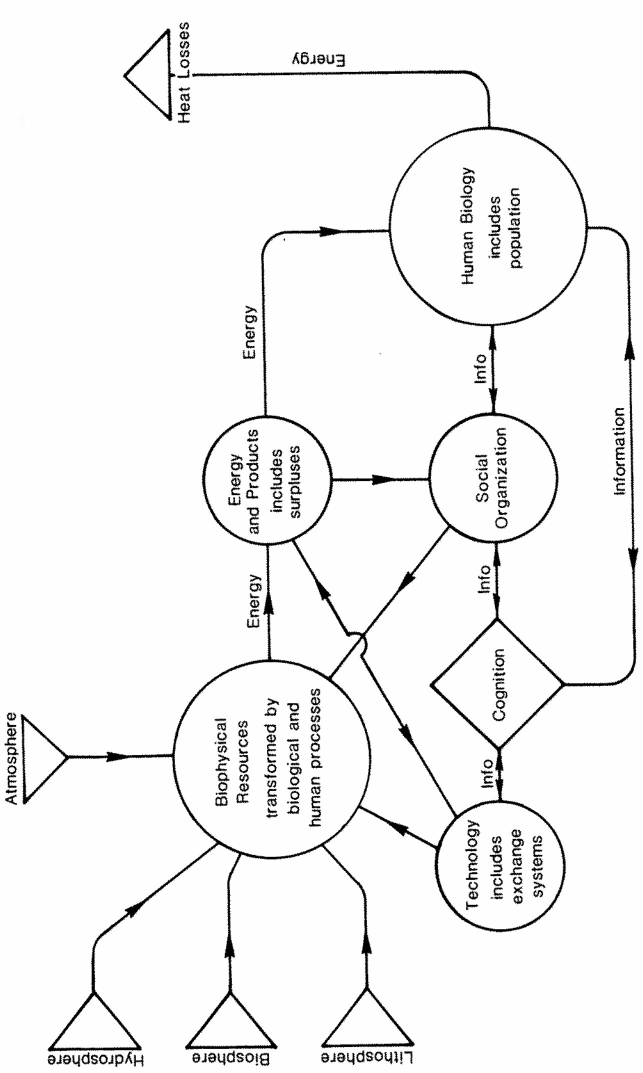

Figure 2-6. Simplified energy cycle for a human ecosystem (does not include storage function). Based in part on Bennett (1976).

nately overlooked by many environmental scientists and ecological anthropologists. The diachronic approach to ecosystems is indeed productive, and it is applied in Chapter 15 to consider cultural adaptation.

Unique character of human ecosystems

In concluding this chapter on environmental systems, it is appropriate to introduce the human ecosystems that are the primary focus of this study. Human ecosystems differ from modal biological ecosystems in kind as well as in degree. For one thing, information, technology, and social organization play inordinately greater roles. More critically, human individuals and groups have unique capacities for purposive behavior, involving (a) the matching of resources with objectives, (b) the transforming of natural phenomena in order to meet these objectives, and (c) the capacity to think about these processes objectively without actually implementing them (Bennett, 1976:35–6).

The pivotal role of human cognition is illustrated in the greatly simplified energy cycle shown in Figure 2-6, which omits the storage functions for "human biology" (population), "technology" (skills and capital), and "energy and material products" (surplus). This role is illustrated both by value systems and goal orientation that are not characteristic of simple ecosystems (Bennett, 1976:Chapter 3) and by the significance of group attitudes and decision-making bodies in the complex societies of the historical record. Similar differences will characterize any food-chain model devised, at least for complex societies, where the trophic levels will comprise a hierarchy of socioeconomic sectors.

The importance of the cognitive role will be discussed further in Chapter 13, but it is important to appreciate at this time that goals, values, and perceived needs are critical in understanding human actions and that culture, perception, and behavior condition the way in which individuals and societies interact with their environments. In particular, geo-archaeological and bio-archaeological research are directed not only at elucidating environmental resources and constraints but also at understanding resource utilization and human intervention within a given environment.

PART II

Foundations