AN ARCHAEOLOGICAL THEORY OF LANDSCAPES

by

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SIGNED: __________ Michael P. Heilen __________
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DEDICATION

To my wife, Jennifer, and my two daughters, Sophia and Naomi, who have given me the strength and determination to succeed, and to my parents, Robert and Marie, who always knew it was possible.
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ABSTRACT

Recent decades have seen a surge of landscape concepts in archaeology. Despite strong, growing interest in landscapes, landscape archaeology lacks theoretical and methodological consistency and coherence. To address this problem, I develop a general, integrative framework for landscape archaeology.

I argue that landscape concepts have a deep history in anthropological debate. Disagreements between landscape approaches are framed as recapitulations of an ongoing historical dialectic in anthropology. I suggest that fundamental binary oppositions in landscape archaeology can be understood in terms of the epistemological and philosophical distinctions between what Sahlins (1976) has termed cultural logic and practical reason. Optimistically, I offer the working hypothesis that landscape studies may form the synthesis of this entrenched dialectic.

I argue that landscape perspectives in archaeology benefit from approaches in geography and ecology, but ultimately artifacts and behavior–based models will need to be built to explain archaeological landscape patterns. Drawing upon behavioral archaeology, I introduce the concepts of archaeological and systemic landscapes and argue that this distinction is critical for making inferences about systemic landscape processes from archaeological landscape patterns. Further, I consider the relevance of scale issues in analyzing landscape patterns and processes.

In contradistinction to current approaches that highlight the role of perception and ritual in cognized landscapes, I argue that landscapes are also cognized according to
techno–functional categories and suggest that in many cases, how landscapes are
cognized is intimately related to how they are used.

To model landscapes, I suggest that landscapes are networks and may share some
properties with other kinds of biological, ecological, technological, and social networks.
I argue that basic properties of landscapes may be allometrically related in manners
similar, but potentially distinct from, relationships observed for non–human organisms in
physiology and biology. In order to counter notions that human behaviors are either
reflexes of environmental conditions or constitutive of environments, I advance the
notion of landscape hierarchy. Finally, I explore aspects of systemic and archaeological
landscapes relevant to a Class III pedestrian survey I directed in southern Arizona, the
Ironwood Forest National Monument survey.
CHAPTER I — LANDSCAPE IN ARCHAEOLOGY

When I started this study, the term “landscape” was approaching an unprecedented level of popularity within archaeology and anthropology. Many authors were beginning to sprinkle their publications with references to “landscape” and others had begun to explore and develop specific “landscape” approaches. While there have been a variety of important theoretical contributions to landscape archaeology, investigators tend to simply apply the term implicitly (with little qualification) as a synonym for “environment,” “environmental milieu,” “ecology,” or “ecological context.” In this sense, archaeological and anthropological usage of the term “landscape” is simply a popular “new” term for long–established concepts and methods. What is entirely absent is a general framework for landscape archaeology.

The increasing popularity of “landscapes” is not unique to archaeology or anthropology. Numerous investigators across a variety of environmental disciplines and sub–disciplines have adopted both implicit and explicit use of the term “landscape.” Despite increasing prominence of “landscape” as a theme, perspective, or theoretical approach, the meaning of the term is often left undefined. Explicit definition of the term “landscape,” when cited or generated, can draw from a wide variety of perspectives and research agendas. Even when explicitly defined, it is often unclear how investigators intend for “landscape” approaches to be differentiated from previously explored processual, behavioral, evolutionary, or post–processual approaches. The wide applicability of “landscape” to divergent research topics and approaches allows for not
only the erosion of long-established disciplinary and conceptual boundaries but for the implementation of almost unlimited, personalized contributions to landscape theory.

In its current stage of development, landscape archaeology does not have to be an entirely new research program to successfully contribute to archaeological method and theory. In fact, just as landscape ecology has built on the contributions of systems and community ecology (Turner et al. 2001), landscape archaeology depends on the theoretical and methodological advances of earlier research programs. To completely abandon earlier archaeological contributions for a weakly defined, chaotically explored research program would leave the study of archaeological landscapes empty and meaningless. At this stage, a general integrative theory of archaeological landscapes is needed.

*Conceptual Organization of this Study*

As a starting point, I examine variation in landscape approaches and attempt to account in some small way for their origins. I argue that much of landscape archaeology is not new but is instead the recapitulation of research themes and interpretive schemata as old as anthropology. Following Sahlins’ (1976) general argument over the relationship between humans and environments but coming to different conclusions, I recognize the contradictions in current manifestations of landscape archaeology as reflecting a historical dialectic in anthropological discourse. While this dialectic today remains largely unresolved, I anticipate the possibility that new formulations of landscape may resolve this long-standing opposition between nature and culture.
In order to understand the current state of the discipline, I take a brief tour of landscape archaeologies, noting their commonalities and differences. A variety of attempts to categorize landscape approaches are observed indicating only partial agreement on how landscape archaeology is practiced. What is evident, however, is that different landscape archaeologies proceed from different assumptions about the relationships between humans and their environments. The nature of these assumptions largely determines how different landscape archaeologies are realized theoretically and methodologically.

The current florescence of landscape archaeologies is not an isolated event within anthropology. Landscape concepts are also prominent in allied fields such as geography and ecology. As these are fields archaeologists tend to pay attention to and borrow from, I examine how landscape is conceptualized in each field. In geography, I point primarily to Sauer’s work, to which a lot of general concepts in landscape archaeology can be traced. Landscape concepts fell out of favor in geography, but have returned more recently with more phenomenological tilts.

As landscape ecology has a number of attributes in common with landscape archaeology, I examine the current practice of landscape ecology. Landscape ecology tends to place heavy emphasis on GIS, issues of scale, and development and testing of landscape metrics. I suggest that, because of these relationships, landscape ecological studies have implications for landscape archaeology. I observe that parallel issues in scale, quantification, and units of analysis are important for both landscape ecology and landscape archaeology and that the debate over the site concept and archaeological
survey methods is mirrored in the struggle between gradient and patch analysis in landscape ecology. In light of these interdisciplinary similarities, I evaluate the potential for landscape archaeology in terms of gradient (distributional archaeology) and patch (site–based archaeology) analysis. I do not advocate one over the other as each has its positive attributes and drawbacks, but assert that in either case archaeologists need to develop better understandings of how archaeological patterns relate to systemic behaviors. Approaching anthropological problems at a landscape scale overcomes some of the myopia of site–based investigations, but also makes increasingly apparent the gaps in our knowledge of the complex dynamics of people–material systems.

As landscape archaeology necessarily entails increased attention to issues of scale, I explore different components of scale as they relate to archaeological and systemic context phenomena. I organize the discussion according to social, spatial, and temporal scales. My intention is not to comprehensively address issues of scale, but to highlight important issues. Indeed, some ecologists argue that the central focus of the entire discipline of landscape ecology is scale, so I could not hope to offer full comment on the same issues in landscape archaeology.

My main point here is to emphasize that there are a wide range of scales along which systemic and archaeological phenomena can vary and that we have precious little appreciation of how these scales interact or how scale changes affect analytical results. Behavioral archaeologists argue that human behavioral variation can be recognized at three scales: 1) *interaction scale* – discrete interactions between people and artifacts; 2) *activity scale* – synchronically and diachronically variable activities performed by
individuals, households, and task groups; and 3) systemic scale – synchronic and
diachronic variation in the organization of one or more behavioral systems (LaMotta and
Schiffer 2001). These scales in behavioral archaeology basically capture social, spatial,
and temporal variation in scales but little research has been conducted on how to identify
relevant scales. I suggest that a lot of problems in archaeological interpretation and
inference building result from this huge knowledge gap. Like other investigators, I argue
that incommensurability between research projects and disagreement between analytical
results relate fundamentally to incommensurability in scale and units of analysis. In
terms of temporal scales, I suggest that limited understanding of how the coarse temporal
resolution of most archaeological materials relates to finer temporal scales of modeled
human behavior is a major problem area requiring much future research. The temporal
scales at which ethnographic, ethnoarchaeological, and modern material studies are made
are completely out of sync with the temporal scales of archaeological observations. In
terms of spatial scales, I offer a simple way to quantify scales as a combined measure of
grain and extent. I do not suggest that this solves any major problems with spatial scale,
but could at least allow investigators to monitor how analytical results between studies or
between landscapes change with scale.

As a possible foundation on which to develop increased understanding of scale
issues in landscape archaeology, I introduce the concept of landscape allometry.
Allometrically related variables change at different rates and can be described in terms of
power laws (see equation 4.2 in chapter 4). I note that allometric relationships are rife in
biological systems and that landscape ecologists are beginning to recognize allometric
relationships in landscape ecological systems involving both biotic and abiotic components. The fascinating thing about allometric relationships is not so much their ubiquity, but their regularity. The same relationships can apply across all levels of biological organization essentially encompassing all life forms. Similar relationships may also extend to extra-somatic levels of organization. Increasingly, it appears that fundamental properties of networks as metabolic and extra-metabolic circulatory systems are responsible for these emergent properties. Thus, it seems logical to hypothesize that such relationships also exist in landscape network systems. Though the data are problematic, I suggest that allometric relationships occur within some aggregated ethnographic data and that scaling exponents of these relationships could result from functional and topological relationships with landscape networks. Residential move distance and population density are two allometrically related variables that may be explained partially by network typologies and the energetic requirements of human systems. Although I do not really explore the topic here, allometric scaling relations for fundamental variables, such as energy or some other common currency, can allow archaeologists to connect behaviors and trends across continua of techno-ecological strategies and socio-economic complexity, rather than focusing their efforts on problematic typologies (i.e., hunter-gatherer, village agriculturalist, complex society).

Having addressed some basic aspects of landscape archaeology – where it comes from, how it tends to be performed, how it relates to other environmental disciplines, and what are some of its central issues – I move on to address one of the more knotty topics of landscape archaeology: *landscape perception*. It is in this topic along which many
lines are drawn in landscape archaeology and remains one of landscape archaeologies’ most divisive issues. Building upon the argument of historical dialectics in anthropological discourse, I argue that systemic landscapes are the product of human–environment interactions. Landscapes are neither entirely natural nor entirely cultural. Further, how people interact with environments is directed by perception, but perception is based on ethno–taxonomic classification of landscape ecological elements. Landscape elements are behaviorally meaningful units—such as landforms, sedimentary facies, cultural facilities, places, or resource patches—that are comprehended as wholes. How people define landscape elements ultimately depends on how people use elements. Landscape cognition guides landscape interaction but is based upon the utility of ecological resources as those resources function within a techno–ecological system. Thus, I argue that landscape perception and landscape functionality are interrelated.

In order to develop this concept, I direct attention to a variety of ethnographic and historic examples. I do not intend to be exhaustive here, but only underscore the point that cultural logic and practical reason are not as incompatible as Sahlins (1976) would have us believe. Fundamentally, landscape perception and landscape action are functions of economic and techno–ecological modes of production. To further underscore this point, I discuss how the perception of environments is modeled in terms of optimal foraging theory and evolutionary ecology. These models suggest that how organisms perceive their environments relates to how organisms obtain energy from their environments. The same kinds of functional, energetic requirements should also apply
to human systems but human systems should occupy a greater range of variation than systems of other organisms.

Having argued that landscape cognition and landscape action are fundamentally related to how people functionally interact with their environments, I introduce another central point of this study. *Landscapes are networks*. While the idea of landscapes as being networks seems to crop up fairly often, investigations rarely develop the implications of this topology. The conceptualization of landscapes as networks has crucial implications for how we model landscape–level interactions and landscape formation and for how we quantify archaeological and systemic phenomena.

Investigations of archaeological and *systemic landscapes* generally attempt to explain systemic scales of behavioral variation. This investigative approach clears the way to conceptualizing landscapes as spatial manifestations of networks of activities linked by flows of matter, energy, and information. A behavioral system is “a set of patterned behaviors that articulates a human group with the physical world around it and with other semi–independent behavioral systems. A behavioral system includes people and *only* those elements of the material worlds with which they actually (i.e. physically, visually, chemically, acoustically) interact” (LaMotta and Schiffer 2001:27). Conceptualized in this way, landscape activity networks are composed of one or more linked behavioral systems. Landscapes do not have to be the territory of a particular group or some large–scale construct such as culture area. *Systemic landscapes* are simply networks of related, patterned, human activities. A convenient way to model *systemic*
landscapes is as networks of places connected by routes, but other formulations that account for variation in scales of behavior can also be modeled.

An important point that interdigitates with this theme is that archaeological landscapes are not systemic landscapes. Objectively, sites are not ipso facto places or routes. Archaeological sites can only be inferred to correspond to systemically realized places through careful behavioral inference. At a basic level, sites are concentrations of archaeological materials that are defined as archaeological sites through methodological schemata. In terms of behavioral systems, archaeological sites interpreted as places may represent not a single place, but multiple intersecting places linked to one or more landscape networks. Thus, in inferring systemic landscapes, it is perhaps most relevant to focus on artifact and feature associations, rather than sites, which can be inferred to have had functional relationships with patterned activities.

By their very definition, as networks of activities connected by linkage factors, behavioral systems imply functional integration. Functionally integrated landscape networks are intuitively satisfying constructs that have been empirically demonstrated through ethnoarchaeological research. Different places on the landscape are used for functionally linked activities comprising an integrated, functional system. However, without careful archaeological inference, it is not empirically justifiable to interpret sites as functional components of larger behavioral systems. It is more easily justifiable to infer activities from behavioral aggregates of artifacts and/or features. Archaeological sites are concentrations of artifacts and/or features potentially relating to a wide array of phenomena occurring at a variety of different times. Interpreting the functional roles of
archaeological sites as places within landscapes is questionable and may not provide much useful or reliable information about land use and settlement systems.

In order to counter the notion that landscape networks are entirely products of cultural design or that landscape networks are determined by environment I introduce the concept of landscape hierarchy. Hierarchy theory posits that higher level processes guide and constrain lower level processes. While the reverse can also obtain, the notion of landscape hierarchy is very important to landscape–scale investigations. This is because extremely general, high level patterns and processes may exert strong influence on many lower level patterns and processes. As a simple heuristic example I compare and contrast the Sonoran Desert Basin–and–Range physical environment with arid Australian environments. There are some striking differences between the two environments which might have some strong evolutionary ecological implications. Although there are certainly many other important factors involved, I suggest that some of these basic differences in physical environments and landscape formation processes could exert influence on the development of techno–ecological systems of production and cultural trajectories. As another example of landscape hierarchy that has direct implications for basic properties of archaeological landscapes, I examine the Bintliff–Snodgrass model for offsite ceramic distributions in Europe and the Middle East. By comparing basic archaeological data (artifact densities) from studies conducted in several different regions, they show that huge meta–regional variation in landscape metrics results quite clearly from very broadly scaled variation in climatic and sedimentary regimes. I suspect that if archaeologists were to conduct similar kinds of meta–regional, inter–landscape
studies we would find more evidence of broadly scaled hierarchical processes and patterns. A major problem, however, is finding consistently and reliably obtained measures of important landscape properties that can be used to monitor such broadly-scaled variation. Further, these properties cannot rely entirely on independently measured environmental variables but must also incorporate archaeologically and behaviorally relevant quantities.

I advocate a theoretical framework for landscape archaeology that: 1) expressly acknowledges the difference between archaeological and systemic landscapes; 2) pays close attention to issues of scale; 3) seeks evidence of the scaling relations of archaeological, ecological, and behavioral variables; 4) models landscape formation as the interaction of cultural logic and practical reason; 5) and formulates landscape structure according to network topologies. I illustrate some these concepts using examples drawn from current anthropological and ecological literature, Julian Hayden’s (1965, 1967, 1976a, 1976b, 1998) work in the Sierra Piñacate of Northwest Mexico (Heilen 2001, 2004), Reid and Heilen’s (2005) work at Sanford Ranch in southeastern Arizona, and from a Class III archaeological sample survey I directed in southern Arizona, the Ironwood Forest National Monument (IFNM) survey (Reid and Heilen n.d.). By way of illustration, I model several different kinds of systemic landscapes that can be inferred to have occurred within the IFNM. I do not argue that these models can be used to interpret the disposition of all archaeological remains within the IFNM. I only describe the basic behavioral patterns of different groups as they pertain to interactions with local environments and resources. In each case, I envision landscape interactions as
taking place according to different network topologies. As each of these models pertains to ethnographic and historic evidence, each of these landscape networks shares some historical network connections with previously existing landscape networks. Interestingly, as local environments and their resources become increasingly incorporated into larger political–economic structures, local landscape networks become integrated into larger and larger political–economic networks. Over time, the functionality of different places changes as do flows of matter, energy, and information through evolving landscape networks.

Finally, I explore some global properties of archaeological landscapes and discuss their implications. Archaeological landscapes are the cumulative result of multiple behavioral systems operating over contiguous spaces for long periods of time. In this sense, archaeological landscapes are palimpsests of the archaeological residues of numerous synchronic and diachronic places, routes, activities, and behavioral interactions. Archaeological landscapes are, in a sense, analogous to Cowgill’s (1970) physical finds population.

*Landscape Dynamics*

Binford (1980:4, ital. added) has argued that “the archaeological record is at best a static pattern of associations and covariations among things distributed in space.” He argues that it is the archaeologist’s task to interpret dynamic living systems from static patterns (Binford 1980). While the archaeological record as recorded is static unless re-recorded, I argue that archaeological patterns are not static. At the very least, behavioral
systems integrate with archaeological landscapes through processes of reclamation, modification, and disturbance. Many studies have shown that disturbance processes such as freeze–thaw, bioturbation, erosion, trampling, agricultural plowing, construction, and artifact collection result in the redistribution, loss, and/or weathering of artifacts. Models of site formation now generally attempt to take disturbance processes into account. Moreover, behaviors within and between behavioral systems may reuse, recycle, or reclaim materials from locations of discard, abandonment, or storage. As any archaeological surveyor knows, temporal changes in biological and hydrological activity often result in temporal variability in ground conditions and surface visibility. More disturbing, Shott et al. (2002) has shown that temporal variation in weather conditions differentially exposes surface artifacts to such a degree that many common statistical measures of archaeological assemblages vary considerably as a result of when archaeological observations are made.

In short, archaeological landscapes are dynamic systems. Archaeological landscapes may even function as complex, hierarchical networks of spatially and temporally linked disturbance processes. The dynamic nature of archaeological landscapes implies that the local and global properties of archaeological landscapes may be interesting in their own right. Systemic behaviors responsible for initial formation of archaeological contexts may only be a starting point for long–term processes that transcend the longevity or persistence of behavioral systems archaeologists are interested in exploring. Past and present behavioral processes occupy nodes within larger networks of interacting energetic processes (i.e. mechanical, chemical, thermal, acoustic) to form
archaeological landscapes determined by the interactions of both living and non–living components.

In order to explore some of the basic properties of the IFNM archaeological landscape, I examine the distribution of site sizes. Although archaeological site size distributions and settlement size distributions have been explored by other authors, I look at site size distributions regardless of site chronology, interpreted function, or environmental context. Despite this lack of detail, site sizes follow an approximate power law distribution, suggesting that the distribution of site sizes is not necessarily the product of systemic landscape variables. Instead, I argue that site size distributions may result from natural laws of archaeological matter that may have very little to do with human behavior. As the scaling exponent of artifact density plots and site size distributions are similar, I suggest that the same organizing principles may affect archaeological distributions at a variety of different hierarchical levels or scales of analysis.

Power law scaling of archaeological landscape properties potentially emerges as a result of complex systems of human–environment interactions. The accumulating evidence that many emergent properties relate to fractal networks is compelling, but I caution that the exact reasons for these distributions could result from diverse causes. There is some reason to believe, for instance, that random multiplicative (multiplying random numbers) processes are responsible for power law distributions in properties of archaeological landscapes but there is also some reason to believe that deviations from classic power law relationships result from methodological limitations on the intersection
and discovery probabilities of archaeological sites. My main point here is not to definitively determine the cause of these properties but to illustrate that some of the same kinds of emergent properties that are observed in biological, ecological, and technological systems may also occur in landscape systems as I have formulated them.

Landscape as Representation

When different archaeologists invoke the term “landscapes” they are not necessarily talking about the same kinds of things. “Landscape” is polysemic (Barton et al. 2004b), hence its general usage in scientific discourse can only be taken as ambiguous or vague. Popular usage of the term “landscape” extends from its initial usage as a term for describing specific, emerging kinds of artistic representation, but has since acquired many diverse meanings.

Pictorial landscapes aesthetically capture and represent relatively broad-scale, integrated environmental and cultural phenomena. Pictorial landscapes have the capacity to represent in perspective the interaction of nature and culture, the relationship between wild and built environments, on a canvas much smaller than the things it represents. To some investigators, the development of perspectival, pictorial landscapes in the visual arts corresponds to the capitalistic alienation of land by privileged elite. Pictorial landscapes in this sense are thought to externalize and disembody environments. Pictorial landscapes are not maps, but as objectified representations of commodifiable resources, they are closely tied to cartographic maps, as devices for carving up space into transactable units (Cosgrove 1984; Thomas 1973).
On the other hand, pictorial landscapes are representations of particular environments from the perspective of particular human observers. Depending on artistic school, cultural background, and cosmology, a pictorial landscape reduces an existing, yet chosen “landscape,” to its essence as interpreted from a given perspective. Pictorial landscapes organize the apprehended world within perspectival space according to cultural ordering schemes.

Interestingly, McGlade (2003:115) considers the work of post–Impressionists, such as Paul Cézanne, as a “challenge [to] the “elaborate fiction” of perspectival space as an adequate framework…for legitimate knowledge of the world.” The subsequent development of analytical Cubism with its “exploration of spatiotemporal dynamics signaled the emergence of nonlinearity in the visual arts” (McGlade 2003). Archaeologists interested in ideational or symbolic landscapes and archaeologists interested in investigating chaos, nonlinear dynamics, and complexity find historical analogs and sources of inspiration in the history of European visual arts.

Given the interpretive history of landscape, the term “landscape” can be used to refer to a great many different things. In both popular and academic discourse, the term itself has been almost endlessly elaborated. We discuss “scapes” as all kinds of physical and conceptual arrays: skyscapes, seascapes, mediascapes, moneyscapes, bodyscapes, microscapes, eventscapes, viewscapes. This terminological proliferation and confusion is not entirely unexpected. Landscapes are multifaceted, heterogeneous, and holistically inclusive. Landscapes are omnipresent and individualized – easy to find and hard to
define. But, to be a useful conceptual basis or a set of modeling tools, a theory of **archaeological landscapes** cannot be anything and everything.

*Landscape as Environment*

The implicit equation between landscape and environment in landscape archaeology signals renewed interest in investigating relationships between people and their environments. Landscape archaeology, though appearing in many guises, is in this way a new phase of ecological and environmental approaches in archaeology. A facile equation between landscapes and environment negates the potential of landscape to represent a more integrated formation resulting from the interaction between humans and their environments.

*Landscapes are not prima facie environments.* Landscapes are the product of continuous and discontinuous, multi–scalar, interacting natural and cultural processes. Classically “natural” and “cultural” processes may in some cases be so interlinked as to suggest mutual causality and processual inter–dependence (i.e., agricultural de–vegetation, soil loosening, and erosion) requiring terminology (e.g., socioecological processes) that acknowledges these linkages (Barton et al. 2004b; Butzer 1982; van der Leeuw and Redman 2002).

Attention has shifted from deterministic viewpoints. To many archaeologists landscapes are the physical and ideational embodiments of what Julian Steward (1977) called cultural ecosystems. Archaeologists can no longer remove human systems from the particularities of their environments any more than they can interpret human systems
as the cultural reflex of environmental conditions. Now, archaeologists embed human systems within intricate webs of ecological interaction and significance.

Why Are Landscapes So Important Now?

Rising concern over human impacts on local and global ecologies motivates archaeologists to view human systems as determining fundamental characteristics of occupied and exploited environments. Developments in environmental sciences and in world events increasingly demonstrate the sweeping impacts of human energy consumption (i.e., ecological footprints, global warming), growing economic dependence on globally distributed markets and resources, and human vulnerability to environmental degradation and catastrophe (Field 2001; Holland 1995; Vitousek et al. 1997). Growing media and multidisciplinary attention to human–induced environmental wasting may be partly responsible for archaeologists’ renewed willingness to situate humans as potentially destructive (as well as vulnerable) agents within larger ecological networks.

As a number of recent volumes attest (Redman 1999; Redman et al. 2004), human systems are coming to be viewed as major disturbance regimes. As agents with short–term goals and limited knowledge of the future, the relationship of humans to their environments is framed as a deep history of pervasive human impacts (Amarosi et al. 1997; Andel et al. 1990; Butzer 1982; Denevan 1992; Grayson 2001; Kohler 1992; Redman 1999; Simpson et al. 2004). Landscape archaeology as an archaeology of human impacts implies that human behaviors intrinsically destabilize ecosystems. Conversely, the growing literature on risk–buffering mechanisms and risk sensitivity
analyses reflects programmatic concern with human vulnerability to both unpredictable environmental variability and catastrophe (Allen 2004; Bamforth and Bleed 1997; Bateson and Kacelnik 1998; Fitzhugh 2001; Herhahn and Hill 1998; Winterhalder et al. 1999). Though different analyses tend to consider how humans either affect or are affected by environments, human systems clearly impact and are impacted by environmental conditions.

Renewed interest in the relationships between humans and their environments is not unexpected. Human societies have created the largest, most significant impacts upon ecological systems of any other species (Vitousek et al. 1997). Human societies extract, transform, consume, and degrade by far the largest portion of available local, regional, and global energy budgets. At the same time, while human technologies have built many artificial environments, they have directly and indirectly altered the courses of many long–standing evolutionary ecological systems. Humans have not extracted themselves from or transcended their environments, but have instead inexorably bound themselves to the ecological consequences of short and long term, high and low impact environmental interactions. By developing themselves as major nodes in ecological networks in order to concentrate and develop social, political, and economic power, human societies have bound themselves to the consequences of previous interactions (Kohler 1992).

A Behavioral Landscape Archaeology

The kinds of questions I intend to address in this study are broad and in many cases open–ended. I do not intend to solve to everyone’s satisfaction a handful of
nagging technical problems. Nor do I attempt to lay groundwork for an entirely new paradigm because I do not think landscape archaeology is a new “paradigm.” By exploring and in some cases developing theory, I do not intend to supplant or nullify the importance of previously developed approaches. Much of what I do in this study is to explore the possibilities offered up through the synthesis and interactions of both complementary and competing approaches in archaeology and allied fields. Thus, in a somewhat Marxist fashion, I explore the current roles and future potential of landscape approaches through a kind of Hegelian dialectical analytical framework. I match one approach against its seeming contradiction or competitor and attempt to find a synthesis that resolves or reduces the contradiction between the two.

I admit at the outset that I am generally concerned with the principles and applications of behavioral archaeology. Despite this theoretical tilt, I also see value in developing bridges to other archaeological theories associated with different perspectives, be they Darwinian, behavioral ecological, Marxist, etc. (Schiffer 1996). As Schiffer (1988) has argued, archaeological theory is multifaceted, heterarchical, and situationally dependent. Perhaps most of all, archaeological theory is often dependent on theory developed for other disciplines and for non–archaeological kinds of research problems (Schiffer 1988).

In my opinion, a lot of general theory is really the rediscovery and remodeling of old ideas. The development of new theory, excepting truly radical cases, most often involves finding appropriate sets of ideas, research settings, and terminology for new problems with old corollaries. I see no problem with archaeologists seeking inspiration
in the thoughts of others. But, like behavioralists, I feel that ultimately we have a responsibility to develop theory that is fundamentally archaeological – whether it is developed internally or stimulated externally – and not simply a loose translation of theories from other fields (Murray and Walker 1988; Trigger 1989).

One broad programmatic contradiction that has emerged in current theoretical discussion is between selectionist and behavioral approaches (O'Brien and Holland 1995; O'Brien et al. 1998; Schiffer 1996). While some comparative discussions of competing research programs might develop postulates that are clearly incompatible, other discussions by leading proponents and founders of research programs are more conciliatory (Schiffer 1996). It is likely a general tendency of new theory to present itself as directly contradicting established theory. Stark contrasts may promote more rapid comprehension of differences, but contrarian posturing is not equivalent to scientific advancement. Though some selectionists have broadly criticized the nomothetic aspirations of behavioral approaches, it is a cruel injustice to suggest that generalities and principles developed through behavioral approaches are either unworkable or so general as to be trivial. Most current archaeological practice relies upon concepts and methods that have long been advocated by behavioral archaeologists, though these general contributions are infrequently attributed.

For instance, while selectionists consider constructed domestic features (i.e., houses, beaver dams) to be phenotypic, knowledge of the differential function of such features – and hence their selective fitness – must be derived from behavioral inference. In another example, a recent article on aboriginal smelting technology uses ethnographic,
historic, ethnoarchaeological, and archaeological data to argue that improved knowledge of the material correlates for technological behaviors is required to interpret high degrees of variability in aboriginal Andean metallurgical technology. Despite this classically behavioral approach, not a single reference to the main architects of behavioral approaches nor to behavioral approaches to middle range theory, inference building, artifact variability, or technology is made (Van Buren and Mills 2005).

**Basic Concepts and Principles**

In this study I advance several critical concepts and first principles that can be used to build frameworks for doing landscape archaeology. First, following the principles of behavioral archaeology (Reid 1995; Reid et al. 1974; Reid et al. 1975; Schiffer 1972, 1987), there should be at least two kinds of landscapes relevant to archaeological discourse: *archaeological landscapes and systemic landscapes* (Heilen 2003). *Archaeological landscapes* are the landscapes of archaeological materials and evidence that archaeologists objectify and operationalize through instances of scientific observation, inference, and analysis. *Systemic landscapes* are the landscapes of past and present behavioral systems in which people–material, human–environment behaviors and activities are performed. Although archaeological and systemic landscape contexts overlap in time and space, the properties of past systemic landscapes are *inferred* from the properties archaeological landscapes (Reid 1995; Reid et al. 1975).

The material phenomena we as archaeologists observe today are *archaeological landscapes*. *Archaeological landscapes* are the cumulative result of behavioral
Figure 1.1 A simplified model of the relationship between systemic and archaeological landscapes.

interactions with systemic landscapes. In one sense, archaeological landscapes are the totality of archaeological manifestations occurring within a given space. Archaeological landscapes can also be temporally and systemically dependent.

In this sense, archaeological landscapes are the material correlates of a particular systemic geography on a given landscape during a given time. Thus, a single arbitrarily defined parcel of land could contain a single archaeological landscape or many archaeological landscapes depending upon how archaeological phenomena are categorized and defined. Multiple, distinct archaeological landscapes within the same
space can be partitioned according to categories such as feature types, artifact types, or time. Further, a single archaeological landscape can be used as a basis for inferring many systemic landscapes.

Systemic landscapes can be conceptualized as a spatio–temporal medium of human–material interactions. People interact with landscapes just as they do with people, tools and resources. In Schiffer's (1972) original formulation of archaeological and systemic contexts, material elements operating within systemic contexts could be subjected to a number of cultural processes during their life cycles. The behavioral chain of an artifact may include procurement, manufacture/preparation, use/consumption, lateral cycling, maintenance, recycling, and discard. Material elements enter archaeological context when discarded or lost (Schiffer 1975). Landscape elements in systemic context, such as cultural features and places, may be subject to similar behaviors (Zedeño 2000).

As a context, or medium, for human interaction with material elements, systemic landscapes are the sum total of landforms, natural and cultural resources, and human modifications to the natural environment with which a particular behavioral system interacted. Although it is possible that an entire systemic landscape could enter the archaeological context at the same time, the incorporation and discard / removal of systemic landscape elements is a dynamic process. Assuming occupation by the same behavioral system, some landscape elements drop into archaeological context over time while other environmental features become incorporated.
Inferences on the nature of systemic landscapes can be built using material correlates that connect archaeological manifestations to systemic behaviors. **Archaeological landscapes** result from the systemic discard or abandonment of landscape elements or features, but components of **archaeological landscapes** may continually re-enter systemic context through reuse, recycling, and scavenging behaviors. **Systemic landscapes** are characterized by diverse sets of dynamic interactions between people and materials. **Archaeological landscapes** are characterized by differential cultural and natural formation processes that distort, alter, or re-organize the material consequences of systemic phenomena.

Second, **archaeological and systemic landscapes are networks**. **Systemic landscapes** are networks of people and places connected by routes or causeways. **Systemic landscapes** are also networks of human activities and ecological interactions connected by linkage factors. Linkage factors organize the exchange of matter, energy, and information between activities, creating networks of behavioral–ecological interactions that generate **systemic landscapes**. Being both derivative of past and present **systemic landscapes** and influenced by ongoing behavioral and ecological processes, **archaeological landscapes** can also be considered networks. **Archaeological landscapes** are formed through a hierarchical network of behavioral and ecological (cultural and natural) processes, the interaction of which form system–level properties of **archaeological landscapes**.

**Landscapes are hierarchical.** Landscapes are formed through hierarchies of processes and are subject to the possibilities and constraints imposed by environmental
conditions and cultural systems. Higher-level, broadly-scaled, spatio-temporal, natural and cultural landscape processes guide or constrain lower-level processes. Lower-level processes may also instantiate higher level processes. Issues of scale become of critical importance here, as changes in scale may often result in shifts from one hierarchical level of processes or patterns to another.

*Systemic landscapes are historical products of people-material interactions.*

Environments do not completely determine behaviors. On the other hand, cultural design, intentionality, or motivation does not completely determine how agents interact with environments. Historical contingency plays a large role in determining how humans interact with their environments, the kinds of processes involved, and the patterns that form from histories of interactions. Non-linear, historically divergent patterns emerge from minor variations in the initial conditions of simple, iterated, deterministic equations. Likewise, minor variation in founding socio-technological strategies and environmental conditions may also result in major, long-term variation in landscape patterns and processes.

*The Ironwood Forest National Monument Survey*

This study stems, in part, from research related to an archaeological Class III sample survey of Ironwood Forest National Monument (IFNM) I directed over the course of 92 field days between June 2002 and November 2003. I use data and insights related to this survey throughout this study and thus provide information here on IFNM survey methodology. Early on, I had hoped to experiment with distributional methodology, but
found that it would not be feasible in the conditions under which survey could be conducted. The IFNM has relatively rugged terrain, mature vegetative growth in places, fair to limited road access, and ground surfaces are punctuated by areas of relatively high artifact and feature density. Discussions with colleagues and visits to potential survey areas led me to believe that broad–scale total station mapping of survey areas would be enormously costly and time–consuming. The BLM wanted a survey of 5,000 acres and needed basic guidelines to be followed, so a distributional survey was eventually dropped from consideration and a more conventional survey was conducted. In a sense, I see this situation as beneficial because it allowed me to think about landscape archaeology from both sides of the fence—those that militate against sites and those that ignore the issue. Future directions in landscape archaeology will have to develop new methodologies that can balance data requirements of theoretical approaches and practical limitations of archaeological survey.

The IFNM survey sampled 5,185 acres of Bureau of Land Management (BLM) lands. A total of 193 person days were expended in the course of survey. This figure does not include a judgmental pedestrian survey conducted by Ned Gaines (University of Arizona), remote sensing and mapping of the Spanish visita Santa Ana de Cuiquiburitac for two separate historical archaeology classes, mapping of modern, undocumented border crosser sites, or general reconnaissance and site visitation.

The IFNM survey used a combination of 19 linear transects (ranging from 1 to 4 miles in length) and 24 ¼–section (800 x 800 m) quadrats. The sample was stratified according to the relative amount of BLM land area in each of 4 hydrological units or
watersheds: Avra Valley, Aguirre Valley, Santa Cruz Flats, and Santa Rosa Valley (figure 1.2). Stratification according to this scheme served two goals. As different valley systems may have different sedimentary regimes, different landscape evolutionary histories, and different use histories, it was felt that stratifying the sample according to hydrological units would capture the most variation in landscape formation processes. As the survey was conducted for the BLM, it was necessary to weight sample selection according to the amount of BLM land within each hydrological unit. Transects, totaling 1389.6 acres, were placed in order to intersect maximal environmental variation. Quadrats, totaling 3795.5 acres, were randomly selected from BLM ¼ sections within the IFNM. As the IFNM survey constitutes only a 4% sample of BLM lands within the IFNM and only a 2.7% sample of the entire monument, large areas of the monument were not sampled. A fair number of sites recorded during previous surveys occur within monument boundaries, but little information on survey methodology is available. Also, the location of State Trust and private land parcels necessarily influence the nature of the IFNM sample. State Trust lands and private lands within the IFNM tend to be biased towards upland / mountainous areas of the monument, so high elevation portions of the monument are not represented as well as other environmental zones (i.e., upper bajada, lower bajada, creosote flats). Sample units were surveyed in random order so as to limit the influence of temporal changes (i.e., changes in weather, ground conditions, methodological drift, personnel changes) on survey results.
Figure 1.2  The location of IFNM sample units with respect to land ownership and hydrological units.

Field observations were made on both “isolated finds” and archaeological sites. Sites were defined according to BLM guidelines. The BLM's Guidelines for Identifying Cultural Resources (Bureau of Land Management 1999:6) defines the minimum criteria for defining archaeological sites as:

1. At least 30 artifacts of a single class (e.g. 30 sherds, 30 tin cans) within an area 50 feet in diameter, except when all pieces appear to originate from a single source (e.g. one ceramic pot, one glass bottle).

2. At least 20 artifacts which include at least 2 classes of artifact types (e.g., sherds, nails, glass) within an area 50 feet in diameter.
3. One or more archaeological features in temporal association with any number of artifacts.

4. Two or more temporally associated archaeological features without artifacts.

**Offsite Versus Onsite Methodology**

The IFNM survey was performed according to the general goals and guidelines of Class III archaeological surface sample survey established by the BLM. The general goal of such pedestrian surveys is to sample target areas (i.e., bounded BLM land parcels within the IFNM) for the presence of sites and isolated finds. While a major goal of such surveys is to locate sites, establish their boundaries, and obtain temporally and functionally diagnostic information, a significant amount of attention is also paid to “isolated finds.” For this survey, every isolated find was recorded, meaning that observations were made on every detected (diagnostic and non–diagnostic) artifact and feature in offsite contexts.

The kinds of observations made depended on the artifact class. For lithics, observations were made on material type, grain, and color, technological categories (i.e., flake, unidirectional core, unifacially retouched flake, utilized flake), and fragment type (i.e., whole, proximal, distal). Additional observations were made in the case of cores: 3 orthogonal measurements on size (beginning with the maximum dimension) and a visual estimate of cortex coverage. Lithics potentially interpretable as tools (i.e., retouched flakes, utilized flakes, bifaces, projectile points, scrapers) were collected. For sherds, observations were made on temper type, temper grain, and apparent temper density, paste color, type and location (e.g., interior, exterior, rim) of surface treatment (e.g., polishing,
scoring, perforation, painted decoration) and fragment types (e.g., rim sherd, body sherd, shoulder sherd). Decorated sherds, rim sherds, shoulder sherds, and unusual specimens were collected. For ground stone, observations were made on material type, grain, and color, interpreted function (e.g., mano, metate, hammer stone), form, location of wear, size dimensions, and fragment types. Only small or unusual ground stone items were collected (e.g., shaft straightener, perforated disc, agave knife fragment). In all other cases, ground stone items were sketched and photographed in the field. For historic metal artifacts, observations were made on general form (e.g., cylindrical can, bucket, sheet), seam type (e.g., single lap, double lap, crimped), presence / absence of solder, size dimensions (e.g., height, diameter), method for opening (e.g., church key, puncture, unopened), modifications, and any identifying marks (e.g., embossed lettering). Only highly unusual metal artifacts (e.g., a 1930s chauffeur’s license, pill case, button) were collected. Otherwise, observations and counts were made on each observed metal artifact type. In one sample (QD–5) very large scatters of dumped historic metal cans and buckets were too numerous to record individually. In this case, observations were made on types believed to be representative, and randomly placed 1 x 1 meter units were used to sample the dump site surfaces.

Every feature observed during sample survey was recorded. Features were categorized according to Arizona State Museum feature types, sketch mapped, and photographed. Measurements were made on overall feature size dimensions, the number and type of elements (e.g., rocks), relationship to the ground surface (e.g., on surface,
partially embedded, embedded), condition (e.g., collapsed, dispersed, intact), and environmental and artifact associations.

For sites, site boundaries were established using compass and pace measurements from GPS–located datums. Sites were photographed, features and diagnostic artifacts were individually documented, environmental attributes (see below) were recorded, and qualitative and quantitative data on non–diagnostic onsite artifacts were obtained.

Due to time and labor budgeting constraints not every onsite artifact was recorded. Although such high resolution data are desirable, the absolute frequencies of onsite artifacts (sometimes numbering in the 1000s) precluded such an effort. Moreover, for high density sites the mapping precision required to accurately measure the spatial location of every artifact would have required the carrying in of expensive mapping equipment to remote locations for a task well beyond the scope of the project. In cases where onsite artifacts numbered fewer than 50, however, artifact locations and attributes were recorded for all artifacts. Where the total number of artifacts exceeded 50, randomly located density plots (1 m$^2$ and 4 m$^2$) were employed to obtain artifact densities and artifact class proportions. In cases where large numbers of flaked stone artifacts occurred onsite, flaked stone was tabulated according to material type, basic technological categories (flake, shatter, core, tool), and the presence / absence of cortex.

Recordation of some archaeological targets did not vary according to onsite or offsite contexts. Features, diagnostic artifacts (e.g., decorated sherds, rim sherds, ground stone implements, retouched flaked stone) were recorded individually, whether discovered onsite or offsite. In a few exceptional cases where onsite diagnostics (e.g.,
metal cans, decorated ceramic sherds, ground stone fragments) occurred in large numbers (> 50), attempts were made to make observations on a representative sample of onsite diagnostics.

For both onsite and offsite contexts frequent observations were made on characteristics of the local environment. Vegetation types (e.g., teddy bear cholla, ironwood, prickly pear), sediment grain (e.g., fine, medium, coarse), sediment sorting (e.g., poorly sorted, well sorted), sediment formation (e.g., alluvium, desert pavement, talus), and landform type (e.g., slope, summit, wash, terrace) were recorded. Judgmental estimations of surface visibility (percentage ground cover) were made by the author. In order to assess the effects of modern disturbances, evidence of modern activities, such as illegal dumping, fire rings, vegetation disturbance, and undocumented border crosser (UBC) activities and materials were also recorded.

At the time of the survey, UBC traffic through the IFNM was very common. Recent, frequent use of the area by UBCs represented an excellent opportunity to gather data on modern material culture and UBC landscape interactions. For UBC materials, attempts were made to describe in detail artifact quantities, artifact types (e.g., shirts, shoes, pants, mementos, backpacks water bottles), manufacturing information (e.g., clothing and food labels), environmental associations (e.g., under palo verde, in wash). In cases, where probable UBC trails were observed attempts were made to obtain GPS track data on trail segments. Although UBCs are a significant management concern to a number of government agencies, such as the Immigration and Naturalization Service, our interests were purely archaeological.
In sum, the IFNM survey generated data on size, shape, location, artifact density, environmental context, and potential functional and temporal associations of 156 surface archaeological sites and several thousand isolated finds. We generated data on individual features and diagnostic artifacts regardless of context as well as data on virtually every artifact observed in offsite contexts. All of the data on individual artifacts, features, sites, environmental context, modern activities, migrant materials, and survey logistics were entered into a large, relational, spatial database constructed by the author for GIS and other quantitative analyses. From this database, locational and attribute data for artifacts, features, sites, environmental contexts, and migrant materials can be extracted and explored in many different ways.

The IFNM Survey And Other Approaches to Survey

Archaeological surface survey, whether it be purportedly “full-coverage” survey or otherwise, is sample survey (Kintigh 1990; Kvamme 1998). Archaeological crew members act as sensors of land surfaces whose task is to detect targets of archaeological interest (e.g., artifacts, features, sites) (Banning 2002). As the sensors of archaeological surface survey are human instruments, there is likely considerable variation between crew members in terms of what kinds of targets they tend to pick up or miss. Archaeological targets, differing in size, shape, and color, will be variably perceived by crew members. Differences in the background (e.g., clast size, shape, and color, vegetation) will also serve to differentially reduce or accentuate the visibility of archaeological target materials.
A principal concern in the design of surveys is “level of effort,” which Schiffer and Wells (Schiffer and Wells 1982:346) define as “the number of person–days expended per square mile.” Intensity, obtrusiveness (“the probability that a given site or artifact will be discovered using a particular survey technique” (Schiffer and Wells 1982:347)), accessibility, visibility, artifact density, feature density, site density, recording time, and sample unit shape and size all affect survey effort (Schiffer et al. 1978). Other things being equal, “crew spacing is the single most important variable affecting level of effort” (Schiffer and Wells 1982:347). Schiffer and Wells build an equation that describes the relationship between crew spacing (S) and level of effort (E) remarkably well:

\[
E = \frac{402}{S}
\]

Many archaeological surveys in the American West are conducted at 20 to 30 meter crew spacings (Cowgill 1990). Crew spacing for the IFNM survey was also within this range, corresponding to a moderate level of effort. The survey required 23.8 person days / mile\(^2\) to complete (Figure 1.3), a figure that fits well with the relationship developed by Schiffer and Wells (1982).
Figure 1.3 The relationship between level of effort (person days / sq mile) and crew spacing for moderately large-scale surveys in areas of fairly low resource density. The IFNM survey is represented by the open square. Adapted from Schiffer and Wells (1982, table 9.1).

Archaeological crew members can only sense a limited portion of the ground surface. Detection of archaeological materials varies according to surface visibility (e.g., percent ground cover), color, size, shape, obtrusiveness, direction of travel, lighting conditions, as well as according to a variety of other factors that serve to obscure or accentuate archaeological targets (e.g. eyesight, rainfall, dust) or affect the temperament or physical comfort of crew members (e.g. temperature, energy level). In brief, there are many factors potentially affecting the detectability of archaeological targets and very few
of these are routinely subject to control by archaeological survey methodologies (Banning 2002; Schiffer et al. 1978; Schiffer and Wells 1982).

One advantage of the IFNM survey is that it was conducted with small, experienced crews (2 to 4 people) operating as integrated, survey units. Most measurements and observations were made routinely by the same individuals, allowing for consistency in measurements and observations. Datum locations were recorded with the same Garmin eTrex GPS unit for the duration of the survey. Although crew members were often subject to high temperatures and extreme conditions (this survey was conducted during one of the hottest, driest years in recorded history), spirits remained high, individual crew members were rugged, well fed, and hydrated, and crew members recognized the need to be both highly observant and consistent.

Despite these reassuring qualities, it is difficult to escape bias in observation and recording of archaeological materials. Archaeological landscapes are dynamic. As a result, the visibility and content of archaeological landscape surfaces is always shifting. Even if every significant detection bias is controlled, it is reasonably assured that past and future detectable archaeological patterns (for the same locations) will differ from those observed during this survey. Little research effort has been expended on this particular topic, but the little research that has been conducted suggests that localized archaeological patterns can vary widely over short time scales (e.g., Shott et al. 2002).

Data developed during the IFNM survey are not amenable to distributional, non–site analyses advocated by some archaeologists (Dunnell 1992; Dunnell and Dancy 1983; Ebert 1992), but such data requirements do not often mesh with the needs and interests of
project sponsors, nor could they be implemented in this area without substantial increase in time, labor, and cost. The IFNM survey must be considered as a sample of a much larger, dynamic archaeological landscape. The data do, however, permit analyses in terms of onsite / offsite contexts and in their current form can be manipulated in a variety of interesting ways. In this and other senses the IFNM data are amenable to landscape–oriented analytical frameworks.
CHAPTER II — LANDSCAPE ARCHAEOLOGIES

Diversity in Landscape Archaeology

*It is both a comfort and a consternation to work long enough to observe firsthand that many of the questions of yesterday’s scholarship can return only in slightly altered form to guide contemporary research (Reid 1997:629).*

In this chapter, I discuss the current state of landscape approaches in archaeology. In doing so, I attempt to find historical and philosophical reasons for the disconnected and inchoate nature of landscape archaeology. I suggest that fundamental binary oppositions between anthropological epistemologies stem from a historical dialectic in anthropology between cultural logic and practical reason. I hypothesize that, despite their current disorganization, further development of landscape concepts could form the dialectical synthesis or mediation between anthropological concepts commonly held in opposition.

The kernels of landscape concepts in vogue today are present in the early writings of a variety of anthropologists and geographers. It is perhaps only the emergence of widely available spatial and relational technologies of analysis (GIS, database software, mapping equipment) and increasingly powerful computational capabilities that provide hardware and software environments for some of these conceptual seeds to be germinated. The capacity to generate, store, compare, and analyze increasingly large spatial data sets in spatial environments has instilled greater confidence that large,
complex spatial arrays are accessible to quantitative analysis. In some cases, these enlarged capacities allow us to address long–debated, fundamental questions in anthropology from “fresh” perspectives.

Hand–in–hand with these new technological advances in data acquisition, storage, and computational modeling are some promising avenues of theory. Namely, advances in complexity theory offer the ability to investigate the properties of non–linear systems and to model how the properties of complex systems can emerge (often unpredictably) from the interaction of relatively simple elements (Lansing 2003). This powerful combination of computing capacity and complexity theory allows us to investigate how large, complex systems (such as systemic landscapes) can form through the interaction of elements that were once considered separately. Game theory also demonstrates how complex social, economic, and evolutionary phenomena can emerge from the interaction of small numbers of relatively simple strategies (Axelrod 1984; Maynard Smith 1982). When simulated according to spatial dimensions, simple game theoretic strategic interactions such as the Prisoner’s Dilemma and the Hawk Dove game exhibit self–organized criticality and power law scaling of relevant metrics (Killingback and Doebeli 1998).

Both game theory and complexity theory have a powerful mechanism in common that makes them highly attractive for scientific investigation. They reduce assumptions by limiting the amount of detail necessary for processes to emerge. Moreover, they place focus not so much on how the attributes of system elements inform the structure and
behavior of larger systems, but on how the *structure of interactions between elements* influences the emergence of system–level properties.

In limiting details, theoretical approaches like game theory and complexity theory are applicable to a wide variety of contexts. They reduce complex phenomena to highly simplified rules or strategies for interactions between very simple elements. They thus allow for the study of complex patterns and processes as the output of highly simplified input. Often, such approaches achieve a common goal of scientific inquiry – they produce informative, unanticipated results. In this sense, they exemplify well the achievement of a fundamental goal of science – analytical tractability.

*Holism versus Reductionism in Archaeological Research*

From a top–down approach, the archaeological examination of complex phenomena, such as landscapes, is a holistic process. Major patterns are recognized by generalizing many landscape details. Such an analytical process is fundamental to recognizing the differences and commonalities of different landscapes. Pattern–recognizing, top–down, holistic approaches can be analyzed comparatively and in this way be used to “make sense” of broad–scale patterns from a comparative perspective. Explanations for the formation of patterns can be hypothesized through top–down approaches, but testing of competing hypotheses is hampered by the detailed complexity of the whole. Boasian enormity of detail and uniqueness of context reduces top–down landscape approaches to relativistic approaches with all their potential trappings.
Bottom–up approaches, on the other hand, can be used to model how complex phenomena emerge through the simpler interactions of constitutive elements. Dumont (1970:10) insists that a “society as conceived by individualism has never existed anywhere for the reason we have given, namely, that the individual lives on social ideas” (Dumont 1970). Conversely, Murdock (1972:19, quoted in Sahlins 1976:95) argues that “culture and social structure are actually mere epiphenomena – derivative products of the social interactions of pluralities of individuals.” While anthropologists (e.g., Durkheim 1887) have long argued that higher–level (e.g., cultural, landscape) processes cannot be predicted from the properties of constituent elements (e.g., individuals, sites), complexity theory offers an alternative solution to this intellectual dilemma.

In terms of the relationship between individual needs and wants and cultural influences, the major social and anthropological question has been: Is the whole the sum of its parts? Do broad–scale patterns, such as cultural ideals, result from broad–scale processes that emerge at a systemic level or are such processes the aggregated result of individual ideals and interactions operating at small, local scales? At face value, Durkheim’s answer is simple:

It is wrong to say the whole is equal to the sum of its parts. By the simple fact that the parts have definite relations with each other, are arranged in a certain way, something new results from the assemblage: a composite being, surely, but one with special properties and which may even under special circumstances become conscious of itself…As…the social being has needs of its own and
among them the need of material things, it institutes and organizes in order to satisfy these needs an economic activity which is not that of this or that individual or that of the majority of the citizens, but of the nation in its entirety (Durkheim 1887, quoted in Sahlins 1976:109).

Durkheim, then, refers to social or cultural systems as something akin to organismal units whose system–level properties cannot be directly predicted from the composition of lower–level system components. Though written before the development of an academic anthropology, Durkheim’s statement above seems to encapsulate in a few sentences the very essence of a general problem that is revisited in landscape studies. Durkheim argues that societies operate at a level of systemic activity and interactions that transcends individual wants or needs. Oddly, his statement seems to anticipate the unanticipated results of complexity theory and its progenitors (chaos theory, game theory). Although Durkheim may have considered society as an independent phenomena and not an emergent property, he suggests that society, as a whole, results from an assemblage of specific relationships between parts.

Complex, system–level properties emerge unpredictably from what we intuitively understand to be the aggregated interactions of individual elements. What is interesting, or new, about complexity theory is that it does not offer an either / or answer to these age–old problems. Complex systems are not the sum of their parts, but their properties can result from the simple interactions of their constituent elements. The bottom does influence, or constitute, the top, but not in the way that has been intuitively anticipated.
The interaction of small, local events and processes across broad scales can generate complex patterns and processes whose structure is not integral to the elements themselves, but emerges spontaneously and globally from local interactions. Individual actions and events, too, when poised at critical thresholds (determined by global interactions) can have dramatic, system–wide effects (e.g., sand–pile avalanches, World War I, the butterfly effect) that belie their scale or relative importance (Bak 1996; Bak et al. 1988; Watts 2002a).

Nonlinear, complex systems are the complexly ordered, emergent output of simple, deterministic input. Complexity emerges at the edge of chaos, between order and disorder. Complex systems are generally far from equilibrium, but remain metastable in basins of attraction. Once sufficiently large perturbations occur, the system may be kicked into a new basin of attraction, occupying a different, metastable state (Lansing 2003; McGlade 2003).

The question then becomes, once a complex system emerges, how does it change? Can the emergent properties of a complex system alter the properties of its constituent elements? How does history come into play? As Marx argued, humans have material needs, yet these material needs (or the impetus behind human–material interactions) are formulated both by biological necessity and cultural imperatives or conceptions. Need, or the impetus behind the actions of individuals or organizations (agents), is a historical product. Needs, or the assumed basis of human techno–environmental interactions, are not simply a matter of pure utility (as in the biological requirements of non–human organisms) but are culturally and symbolically motivated (Sahlins 1976). The simple
interactions of agents can generate complex systems of interaction (i.e. cultures, landscapes), but do the historically generated requirements of the system then motivate the behavior of its elements?

*Perception and Action*

Cultural systems motivate how landscape elements are defined taxonomically and these taxonomic definitions are a function of modes of production. These ethno–ecologies, or folk taxonomies, organize the relationship between humans and their environments. How people view the world is a cultural and historical product that stems ultimately from the ways in which systems derive the energy or currency that maintains them. Ethno–ecological landscape elements operationalize the culturally mediated utility of environmental characteristics. Through definition, landscape elements have functionality that is intrinsic to the system of landscape interaction. This culturally mediated functionality is the historical product of evolving complex systems of landscape interaction and thus motivates how landscapes are cognized and how they are used (Amarosi et al. 1997).

This modeling of landscape interactions takes account of functionality, environmental characteristics, agent decision–making processes, system–level emergent properties, operational and cognized environments, into a historically snow–balling, holistic unit: landscape. This kind of system level – agent level, nature – culture, recursive interaction generates historically contingent products, but how does it begin? Taking a hint from chaos theory, landscape systems may be described in terms of simple
deterministic equations for ecological populations when iterated. Despite the simple nature of such an equation (i.e. where current population is a simple function of population for the previous timestep), minute variations in initial conditions — such as when and where the first people establish a settlement — can result in entirely different and unpredictable (chaotic) histories of population levels (Bentley 2003a). Every form of landscape interaction must be initialized with some sets of pre-existing strategies and “ways of knowing” (or organizing) the world (Amarosi et al. 1997). The interaction of these “founding” or “colonizing” strategies with each other and with culturally or strategically defined elements of existing landscapes generate new systems of interaction and thus potentially new, historically divergent, systemic landscapes with unanticipated emergent properties (Amarosi et al. 1997). As can be seen, this modeling of landscape formation and change, in its formulation of historically contingent structures is, in its capacity for ontogenetically stimulated, strategically diverse interaction, a kind of evolutionary model of landscape formation and change.

**Historical Dialectic of Anthropological Debate**

There is no denying that archaeologists today work from a wide range of epistemological and ontological positions. At the same time it is difficult to escape the impression that many apparently profound differences in “ways of knowing” the past ultimately stem from wanting to know different things about the past (Kuhn and Sarther 2000:79).

In discussing top–down versus bottom–up organization of production, Janusek and Kolata (2004) argue that neither approach successfully captures the socio–political
and historical complexities of state formation and organized production. Instead, they argue for the interaction of local and state–level performances driving the evolution of Tiwanaku raised–field agricultural systems.

Even though evidence globally demonstrates that complex irrigation systems rarely caused states to develop, it is common in archaeology to attribute archaeological evidence of large scale, highly integrated productive systems to the work of efficient, centralized governments…In many world regions, convincing evidence demonstrates that cultural elements once considered as diagnostic of state–directed actions, including monumental construction, craft specialization, and large–scale economic production, were at least as much the product of local kin–based groups as of the elites and leaders who, in some cases, coordinated such activities (Janusek and Kolata 2004).

Interestingly, they frame their argument as a socio–political shift from heterarchical settlement networks to hierarchical settlement networks. In doing so, they disavow arguments that insist on centralized, political design and planning of intensified, hydraulic and agricultural infrastructure (Wittfogel 1957) and instead imply that state formation involves the co–option and manipulation of existing, unplanned settlement networks. Large urban centers, population growth, and monumental architecture followed, but in my view, the formation of the Tiwanaku state may reflect the hierarchical reorganization of existing landscape networks. A similar co–option of pre–
existing, emergent loci of local agricultural production networks, *ahupua‘a* land units, may have also coincided with state formation in Hawai‘i (Allen 2004; Hommon 1986).

A number of investigators have now identified the highly eclectic, diversified variety of analytical approaches that have been placed under the banner of landscape archaeology (Whittlesey 1997; Zedeño 2000). Many have also observed that “landscape” as a term has been in use for centuries. Academic landscape concepts have been available to anthropologists, ecologists, and geographers for more than a century (Sauer 1967a). Yet, over the past decade, perspectives heralding the importance of landscape have reached a critical threshold in anthropology, and these perspectives (as diverse as they appear) seem poised to unleash an avalanche of new ideas about human–environment interactions.

Many landscape approaches seem incompatible with each other in that they are almost diametrically opposed in their fundamental assumptions about the relationships between humans and their environments. An optimistic evaluation of competing perspectives is that the juxtaposition of seemingly incommensurable opposites may generate a new dialectical synthesis in anthropological theory. The synthesis of this dialectic is a mediation between competing trends and approaches, between fundamentally different ways of “knowing the world.” The new synthesis is landscape anthropology.

A pessimistic evaluation, on the other hand, is that the many disparate approaches to theory and method in landscape archaeology reflect fundamental disputes as old as the discipline itself. Perhaps this is an instance where “ontology…recapitulates
methodology” (Sahlins 1976:89). The way different archaeologists view landscapes is conditioned by their experiential and educational background. Archaeologists may simply explore long–standing perspectives allowing only for some changes in terminology and refinements in methodology.

Ultimately, questions raised by landscape archaeologies are about how humans relate to their environments. Do humans create or define their environments according to a cultural logic or do environments determine human behaviors (cf.Ellis and Waters 1991)? How and to what degrees do humans impact their environments, manage critical resources, or respond to environmental changes? Are relationships between humans and their environments significant only insofar as humans perceive or cognize their environments or is human environmental perception derivative of technological interactions with environments (Sahlins 1976)? Are the distinctions between culture and nature, humans and environments, raw and cooked, wild and domesticated, false dichotomies that need to be dismantled (Terrell et al. 2003)? Are relationships between humans and their environments unidirectional, bi–directional, recursive, or something yet unformulated?

Sahlins (1976) frames the debate over the relationships between humans and their environment in terms of the differences between practical action (utilitarianism, functionalism, economy, ecology) and cultural reason (structuralism). He refers to these basic assumptions for understanding human–environment interactions (i.e., culture and practical reason) as the “founding contradiction, between the poles of which
anthropological theory has oscillated since the nineteenth century like a prisoner pacing between the farthest walls of his cell” (Sahlins 1976:55).

To Sahlins (1976), artifacts and technology, central foci of archaeology, are material manifestations of practical reason. In the context of Sahlins argument, artifacts and technology ultimately emanate from and are subordinate to the conceptual ordering of social relations or cultural logic. In contrast to Steward (Steward 1938), who argues that the social and cultural properties of human groups are founded on ecological and technological conditions, Sahlins (1976:132) argues that “[s]ociety is not specified by technology, nor can the former be thought of as an ‘expression’ of the latter. In important respects it is the other way round.” Marx, whose arguments are the inspiration for much of Sahlins’ critique, was equivocal on the subject. Sahlins (1976:131, ital. orig.) interprets Marx and Engels (1965) as arguing for the “social specification of the technological function.” Elsewhere, Marx (1967:372n, quoted in Sahlins 1976:159) argues that “Technology discloses man’s mode of dealing with Nature, the process of production by which he sustains his life, and thereby also lays bare the mode of formation of his social relations, and of the mental conceptions that flow from them.”

Sahlins interprets these and other Marxist positions as meaning that what people produce (artifacts, consumables) and how they produce it (technology, behavior) is not determined by biological necessity but instead results from cultural ordering schemes. Sahlins (1976:55) insists that the conflict between practical reason and cultural logic “will [not] be resolved by the happy academic conclusion that the answer lies somewhere in between, or even on both sides (i.e., dialectically).” Instead, Sahlins privileges the
role of cultural logic in the organization of production and technology to an extreme degree. Sahlins uplifts the importance of historical and cultural contingencies in organizing systemic landscape formation. Landscape perspectives that privilege cultural logic over practical reason may effectively eschew the relevance of issues fundamental to inferring systemic landscape formation processes from archaeological evidence – technology, artifacts, and practical activities and behaviors.

There is nothing revolutionary about many of the concepts that have been positioned as fundamental to understanding anthropological landscapes. These basic concepts (culture, environment, determinism, adaptation, design) have been the bread and butter of anthropological debate for decades. The promise of landscape studies is not that they will finally resolve the debate, but that neither side was fully capable of explaining investigated patterns and processes. Like good and evil, matter and anti–matter, yin and yang, positive and negative, these binary concepts allow more complete views of the world by virtue of their juxtaposition. As apparently tractable, but incomplete pairs of opposites, they only exist as opposites. Landscape is the synthesis of these oppositions.

This is precisely why landscape archaeology often appears merely to be a new guise for long–standing perspectives and approaches. In advancing arguments from a landscape perspective, investigators often assume one or more of the arguments of their predecessors. Investigators make fundamental assumptions about the nature of relationships between humans and their environments.

The formulation of landscape theory, in terms of its generation from larger bodies of anthropological and ecological theory is as a kind of dialectical archaeology.
Landscape is the synthesis of the dialectic of nature and culture. Despite a continued, though perhaps covert reliance on dialectics, landscape theory “attempts to efface the nature–culture dichotomy” (Whittlesey 1997:21). Landscape theory has not been successful in divorcing itself from this basic dichotomy but the erosion of an artificial division between nature and culture is seen by some (Crumley 1994; McGuire 1992; Patterson 1994; Tilley 1994; Whittlesey 1997:21) as “the most fundamental undertaking of landscape theory” (Whittlesey 1997:21). As Tilley (1994:23) writes, “[p]eople and environment are constitutive components of the same world, which it is unhelpful to think of in terms of a binary nature / culture distinction.”

Nature is only separable from culture in cases where humans do not exist. Environments are unaltered by human activity only in the absence of previous human interaction, as in previously unoccupied lands. The arrival of colonizing populations has inevitable consequences, intertwining the histories of people and their environments and generating new kinds of humanized (or de–naturalized) landscapes (Rockman 2003). Investigation and cataloguing of human–initiated ecological and environmental transformations represent one of the resounding themes of the new environmental archaeology. Despite the reciprocal nature of anthropological landscapes, this new trend is largely an archaeology of human impacts (Alroy 2001; Kirch 2004; Martin and Szuter 2004; Redman 1999).
In anthropology, landscape is often conceptualized as either an *externalized*, *objectifiable reality* or an *internalized, subjectified perspective* (Tilley 1994). On the one hand, landscape is viewed as an environment, distinct from and external to human involvement, that exists in—and-of—itself outside of human interactions. In this sense, landscape as environment is a container for human actions and a stage on which human activities take place. Humans may of course modify their environment, but by and large they interact reflexively with environmental conditions or constraints. In this view, humans exploit resources according to how the environment presents itself. The environment is thus a (static) source of utility, functionality, and exploitability. Humans adapt to the conditions environments offer and in doing so they operate under environmentally determined sets of physical, ecological constraints.

On the other hand, landscape is contrastively viewed as cultural construction, intimately derivative of human cognition, as a physico-geographic extension of human intentionality and design. In this sense, landscape is the embodiment of human perception. Components of the physical environment are made meaningful insofar as they are apprehended by culturally determined sets of beliefs and perspectives about how the world works. Landscape as an internalized concept is subjective, personal and sensual, but at the same time socially constructed.

The problem with these two antipodal perspectives is that they make diacritical sense of an analytical construct (landscape) that is general enough to apply to one, both, either, or neither. Externalized views of landscape as environment may be more
A lot of landscape archaeology, but not all, has centered on the notion that drawing archaeological inferences about broad–scale research problems from one or a few sites cannot address the kinds of questions archaeologists are interested in asking (Kohler 1992). In this sense, some landscape archaeology endeavors to monitor the phenomenological or global properties of whole systems of human–environment interactions. Concomitant with such approaches is increasing appreciation for issues of scale and units of analysis (Wandsnider 1998). Archaeologists explore the
appropriateness of units (i.e. artifacts, features, sites, places, landmarks) for understanding archaeological problems of variable scope (Ramenofsky and Steffen 1998; Wandsnider 1998).

In landscape ecology, it is generally shown that landscape processes or patterns, such as variation in humic matter, will vary considerably depending on the scale of analysis. Not only will the type and degree of variation change with temporal and spatial scales, but even the direction of variation. There has thus been a preoccupation with scale – finding the appropriate scale or scales at which to frame a particular problem. Landscape ecologists also generally recognize that there is not often a single “correct” scale at which to view a problem. Most importantly, as archaeologists also increasingly realize, changes in scale significantly change results. I return to these issues in a later chapter.

To many, landscape archaeology is a kind of holistic archaeology. While some important contributions to landscape archaeology should be highly reductionist, or examine the spatial components of a small number of targeted dimensions of analysis, the holistic nature of landscapes is fundamentally correct. Landscape is a socio–ecological totality or aggregate that encompasses myriad complex behavioral, ecological, and material interactions (Pavao-Zuckerman 2000). Appreciation of the complexity of these interactions is building, but understanding of how these interactions ultimately form landscapes is only vaguely formed (Stepp et al. 2003). Anthropologists and ethnoarchaeologists generally monitor only a few basic, measurable properties of systemic landscapes or landscape elements and may lack the appropriate data or
perspective to understand how, beyond a general theoretical level, landscape elements interact to form the whole of a systemic landscape.

The now ancient (Aristotelian) philosophical conflict between reductionism and holism reflects what Corning (1998:134) refers to as a “transgenerational dialectic” in anthropology and the sciences in general. Viewed historically, scientific, theoretical frameworks alternate between emphases on either “parts” or “wholes.” Holling (1995) refers to these disparate epistemologies as “two streams of science.” Contemporary perspectives, such as landscape theory, may search for the interstitial space between these antithetical approaches, building on “the growing appreciation of the inextricable relationships between (and within) wholes and parts, and between various ‘levels’ of organization, relationships which necessitate multi–level, multidisciplinary, ‘interactional’ analyses” (Abel 1998; Corning 1998; Holling 1995).

Archaeological Landscape Approaches

Given the wide range of current questions, we must acknowledge that theories from diverse programs are needed to help answer them…No theoretical program in archaeology — or elsewhere in the sciences — is comprehensive when it comes to explaining variability and change in human behavior. It strikes me as little more than wishful thinking to believe that any program now possesses theories that can explain more than a tiny fraction of the totality of human behavioral variability (Schiffer 1999:167).

The term "landscape,” as applied in archaeology, is an abstract concept that is often applied in multifarious ways. In general, the usage of the term landscape in archaeology is not explicitly defined, but intuitively conjectured. This is perhaps due to the notion that natural landscapes are thought to be composed of landforms or natural
resources, the whole of which can be "comprehended at a glance" (Zedeño 1997). Cultural or social landscapes are thought to integrate natural landscapes and human modifications of existing landscapes (the "built environment"). From this perspective it is difficult to adduce a definition of any particular landscape.

A variety of distinct landscape archaeological approaches have been developed. Some of these approaches present themselves as mutually exclusive (Dunnell 1992; Ebert 1992; Ebert and Kohler 1988). Some aspects of particular approaches truly are. Distributional archaeology, for instance, completely disavows the validity of the site concept. Rossignol (1992:9) sums up the potential problems associated with an "overdependence on the site concept" as: "(a) the neglect of dispersed 'off–site' materials that are important for investigating land use at the regional scale, (b) inexact or vague definitions at the observational level, making data collection and statistical analysis difficult, and (c) a tendency to treat sites as monolithic entities, underestimating the complexity of occupation–component interaction." Many other approaches do not subscribe to non–site methodologies, while others seek some middle ground by attending to concepts such as onsite or offsite (Bintliff and Snodgrass 1988; Cherry et al. 1991; Foley 1981). Despite the potential hazards of site–based research, the choice to retain, suspend, abandon, or modify the site concept ultimately depends on problem orientations, sampling requirements, and determination of the appropriate scale at which research questions are most effectively addressed (Banning 2002; Dewar and McBride 1992; Lucas 2001).
Attempts to classify disparate landscape approaches are based on general methodological trends and research foci. Anschuetz et al. (2001) have identified three general approaches to landscape archaeology as it is currently practiced: (1) settlement pattern analysis and distributional archaeology, (2) historical landscapes, and (3) social formation and symbolic landscape studies. Wandsnider (1998) summarizes approaches to archaeological landscapes in terms of investigated processes and units of observation and analysis. She identifies a historical sequence of landscape approaches: Settlement Survey (1950 – 1980), Siteless Survey (1970s), Greek Siteless Survey (1980s), Historical Ecology (1980s), and Place–Use Studies (1980 – 1990s). To Wandsnider (1998) place–use studies currently in vogue represent a general shift in secondary (synthetic) units of analysis, from sites or settlements to places.

Rossignol (1992:4) defines a landscape approach as a kind of iterative, developmental activity (or scientific process), as "the archaeological investigation of past land use by means of a landscape perspective, combined with conscious incorporation of regional geomorphology, actualistic studies (taphonomy, formation processes, ethnoarchaeology), and marked by ongoing reevaluation and innovation of concepts, methods, and theory.” Rossignol's rather broad definition of a landscape approach is formed in contradistinction to historical landscape archaeology in that it emphasizes the role of geological and ecological variables that she implies are generally ignored by historical landscape archaeological approaches.

Preucel and Hodder (1996) define landscape approaches along a gradient from nature to culture: 1) landscape as environment; 2) landscape as (settlement) system; 3)
landscape as arena of ideological manipulation and power manifestation; 4) landscape as personal experience. This organization of landscape approaches highlights how different perspectives variously balance the influences of culture and environment as well as incorporate different social, spatial, and temporal scales of analysis (Preucel and Hodder 1996).

Other authors have reduced landscape archaeology research agendas to two disconnected, but potentially complementary agendas – those that traffic in depositional and post–depositional formation processes and offer revised sampling methodologies and those that focus on cognized, ideational, or phenomenological landscapes (Given 2004). A simple classification of landscape approaches that acknowledges variation in scientific epistemology and scholarly genealogy is provided by Wilkinson (2003). Wilkinson (2003:4) organizes landscape approaches according to three, broad research paradigms: 1) cultural historical (or landscape history) approaches popular in Europe; 2) processual approaches (“archaeological survey, off–site and quantitative studies, catchment analysis, settlement archaeology, and various ecosystem approaches”); and 3) post–processual (“phenomenological, ideational, and symbolic / religious landscape”) approaches.

Natural and Cultural Landscapes

A basic, implicit distinction that is often made in landscape studies is between cultural and natural landscapes (Sauer 1967a, 1967c). Natural landscapes are generally equated with unadulterated environments whose properties have been only minimally impacted by human activities (Sauer 1967a, 1967c). The validity of natural landscapes as
ecosystemic and environmental formations distinct from human involvement, however, is becoming lessened as ecologists and anthropologists recognize the intense involvement of human activities with landscape processes virtually everywhere people have lived.

Cultural landscapes remain valid theoretical constructs, yet must be recognized as embedded within complex ecological networks involving interactions of many different biotic and abiotic components of culturally mediated (inhabited or exploited by people) environments. Recently, cultural landscapes have been modeled as consisting of four basic dimensions: (1) the formal dimension; (2) the relational dimension; (3) the historical dimension; (4) the cognitive dimension (Whittlesey 1997; Zedeño 2000).

The formal dimension of cultural landscapes refers to the landscape signatures that relate to a group's formal designation of landscape features. The formal dimension is thus composed of the intentional treatment and design of space through the construction of spatially distributed entities such as roads and trails, domestic and ritual structures, and the modification or designation of important landmarks.

The relational dimension involves the relationships between landscape modifications (or behavioral interactions) and social and natural environments. In some sense, this relational dimension is most amenable to GIS analysis in that it generally refers to the spatial relationships between environmental and/or social factors and human impacts on landscapes. Studies of the relational dimension of cultural landscapes are similar to settlement pattern analysis in which the location of sites, features, and isolated artifacts are related to factors such as topography, distance to water and arable land,
vegetation. The relational dimension is also suited to modeling landscapes as networks, an approach advocated by this study.

The historical dimension of cultural landscapes refers to the cumulative impact of human activities on landscapes – landscapes as a sort of palimpsest or architecture in–and–of–themselves. Over time, behavioral interactions transform environments and factors such as the distribution of plants and animals, soil chemistry, and even topography are altered through human modifications of the natural environment. Landscape archaeologists have thus adopted the term “built environment” to refer to additive, cultural modifications.

The cognitive dimension refers to how aspects of the cultural landscape are perceived or conceptualized. The cognitive dimension of cultural landscapes has the most indirect material manifestations and in this sense is the most difficult to interpret and explain, especially when lacking detailed information regarding the conceptual organization of beliefs and worldviews. At present, the cognitive dimension is perhaps best studied with reference to historically known people, where we at least have a concrete sense of how people viewed and understood the landscape around them. It may be possible, however, to develop principles that link these four dimensions, such that properties of the cognitive dimensions of landscapes can be predicted or inferred from properties and performance characteristics of analytical units observed along formal, relational, and historical dimensions.
CHAPTER III — RELATIONSHIPS BETWEEN ECOLOGICAL AND ANTHROPOLOGICAL LANDSCAPES

Introduction

In this chapter, I place landscape archaeology within larger domains of scientific inquiry. I draw attention to relationships between landscape archaeology and landscape studies in other environmental disciplines. I discuss how basic landscape concepts (i.e., cultural landscapes) have their origin in geography and ecology. I argue that significant common ground exists between landscape archaeology and landscape ecology and that landscape ecological studies involving competing analytical frameworks, issues of scale, landscape metrics, and survey techniques are directly relevant to landscape archaeology. Although I argue that developments in landscape ecology and geography can contribute to a more refined landscape archaeology, I caution that models in landscape archaeology are best built from the ground up.

An early proponent of landscape concepts in geography, Carl Sauer (who was a colleague of Kroeber’s at Berkeley) typologized landscapes as either natural or cultural. While Sauer recognized ancient, extensive, human involvement in the formation of landscape patterns, his notion of the relationships between people and landscapes is largely unidirectional. In this rendering, human landscape interactions occur as environmental manipulations and interventions (Sauer 1967b, 1967d). At the time, he and other geographers were reacting against “environmental determinism.” To Sauer, human impacts on natural landscapes formed, or determined, cultural landscapes and not so much the other way around. Current approaches redefine cultural landscapes to be not
the cumulative product of human impacts but the physical manifestation of culture process (Amerlinck 1998). Perhaps more so in this “new” sense, anthropological (systemic) landscapes represent the multivariate, complex relationships between people and land, nature and culture, as a continuous, recursive process of socio–ecological interactions.

To be fair, Sauer envisioned his approach to cultural landscape formation in opposition to environmentally deterministic approaches. In defining landscapes, Sauer sought to investigate geographic environments as resulting from the interaction of both physical (non–human) and cultural processes. He thus considered geomorphological and ecological patterns – “land and life” – as resulting from mutually influential, organically interrelated processes:

The facts of geography are place facts; their association gives rise to the concept of landscape. Similarly, the facts of history are time facts; their association gives rise to the concept of period. By definition the landscape has identity that is based on recognizable constitution, limits, and generic relation to other landscapes, which constitute a general system. Its structure and function are determined by integrant, dependent forms. The landscape is considered, therefore, in a sense as having an organic quality (Sauer 1967a:321-322).
With this interplay of spatial configuration, analytical unitization, and interacting cultural and natural processes Sauer conceived the study of landscapes as the science of “synthetic areal knowledge” (Sauer 1967a).

**Landscape Ecology**

Some archaeologists have advocated the construction of models “from the ground up” over the adoption or adaptation of models developed for other disciplines. While the need to develop explicitly archaeological models definitely exists, there are cases where related disciplines have explored relevant issues more fully. Theoretical constructs from other disciplines have provided useful frameworks for archaeological analysis (i.e. foraging theory, central place theory, information theory, optimality theory, complexity). Landscape ecology is a discipline that shares several fundamental problems / issues with landscape archaeology:

1) the issue of scale  
2) inference of process from spatio–temporal patterns  
3) increasing dependency on GIS for data analysis and display  
4) analytical incorporation of existing environmental data sets  
5) development and testing of landscape metrics for pattern description and analysis
Given similar goals and problems in landscape ecology, I suggest that the discipline of landscape ecology be mined for concepts and methodological tools that can be applied to landscape archaeology. I do not advocate a direct “mapping on” of landscape ecological concepts and methods, but suggest that, at least in some cases, landscape ecological models may be directly applicable to archaeological problems. In other cases, issues more generally related to spatial quantitative analysis can be drawn from. We can benefit from using landscape ecological concepts comparatively or as sources of inspiration. Thus, a brief survey of landscape ecological concepts and principles relevant to archaeological theory is in order.

Landscape ecology developed for decades in Europe before the discipline gained prominence in North America during the 1980s. Landscape ecology, as a discipline, did not depart wholesale from other ecological frameworks, but instead developed a more explicitly spatial framework for analyzing ecological systems. In a general sense, landscape ecology attempts to “couple the observation that landscape mosaics have spatial structure with topics that have interested ecologists for a long time” (Turner et al. 2001:12). Landscape ecology has long recognized “the integral relationship between humans and the landscape” (Turner et al. 2001:12), providing substantial common ground between landscape ecological perspectives and current anthropological perspectives (e.g., socio–natural studies). Like archaeology, landscape ecology has the potential to crosscut many disciplines because it allows for the capacity to evaluate the “total environment.” Most importantly, it acknowledges strongly the key roles humans play in the formation and structure of landscapes. The primacy of human involvement in
landscape ecological formation is partly related to the fact that most studies in landscape ecological studies make use of modern environmental data sets for areas where human impacts are common and pervasive.

In modern times, landscape transformations, the built environment, are increasingly abundant. The construction of transportation networks, development of agricultural fields, commercial and industrial centers, residential neighborhoods, waste facilities, etc. have prominent effects on landscape patterns and processes as disturbance regimes. What landscape ecological studies tend to lack (and archaeological studies can provide) are reconstructions of long-term systems of interaction between humans and landscapes. Melding complimentary aspects of the two approaches could potentially yield discourse and insights relevant to both disciplines.

Current developments in landscape ecology draw upon theoretical frameworks also of interest to archaeologists: fractal geometry, percolation theory, and complexity theory. Fractal geometry is of interest to landscape ecologists because it quantitatively defines patterns that are similar over wide ranges of scales, allowing for the potential extrapolation of spatial patterns across scales (i.e. fine-scale sampling extrapolated to broad scale regions). Moreover, fractal dimensions may significantly affect how biological agents or organisms interact with landscape elements (Kallimanis et al. 2002; Ritchie 1998). Percolation theory is of interest to landscape ecologists for evaluating the spatial structure of landscapes (Gardner et al. 1987; O'Neill et al. 1988). Percolation theory investigates “the size, shape and connectivity of habitats as a function of the percentage of a landscape occupied by that landscape type” (Turner et al. 2001:19). Self-
organized criticality alerts landscape ecologists to the potential for complex systems to be self–similar across wide ranges of scales and describable across scales according to power law statistics (Bak 1996; Bak et al. 1988; Turcotte et al. 2002).

All of these theoretical frameworks in some way concern issues of scale. They represent attempts to address the vexing observation that many patterns and processes are scale dependent. Changing the scale of an analysis or changing the units of analysis has potentially dramatic effects that complicate the comparison of studies conducted from disparate scales. They thus pertain to two fundamental problems: 1) how can we identify the appropriate scale(s) at which to investigate processes of interest; 2) how can we connect patterns and processes across vastly different scales (Levin 1992)? These issues of scale are just as important to archaeologists as they are to landscape ecologists. This obsession with scale is common to both disciplines and thus can be considered a very important common ground between the two disciplines. However, we cannot assume that the specific implementation of these general issues is complementary between disciplines.

*Pattern to Process*

In order to seek common ground between the disciplines, it is necessary to review key concepts in landscape ecology in order to evaluate their complementarity or correspondence with key archaeological concepts. One major difference between the two disciplines may be the concept of landscape itself. Landscape concepts in archaeology generally involve holistic accounting of human–environment, spatio–temporal dynamics,
but are often rather intuitive, weakly defined, and highly variable between landscape studies and investigators. Landscape concepts in ecology are more concretely defined, quantitative, and reductionist and demonstrate general agreement about how landscapes can be defined, measured and analyzed.

Relationships between the spatial structure of resources and subsistence behaviors have long been of interest to archaeologists (Harpending and Davis 1977). One of the major goals of landscape ecology is the developing knowledge of ecological processes through interpretation and analysis of ecological patterns. This is because ecological spatial patterns and processes are thought to act recursively. This primary goal – interpreting process from pattern – has proven difficult to achieve. Wu (2004) claims that much effort in landscape ecological analysis is in the examination of ecological patterns without any clear attempt to model or identify relevant ecological processes. Wu (2004) argues that landscape ecological investigations that do not contribute to the investigation of ecological processes should not be pursued.

*Landscape Analysis: Gradients or Patches*

A fundamental unit of landscape ecology is the *patch*. Patches are discrete spatial areas that share a common attribute(s). A patch might be a patch of trees, a patch of a particular ecological association, a patch of grassland, a patch of fertile soil. In terms of archaeology, a patch can also be a landscape element such as a patch of cultural debris or disturbed soil. Many landscape concepts and related metrics are designed to describe patches and their spatial relationships within a landscape mosaic. From a patch–based
perspective a landscape is a spatial mosaic of patches (Hargis et al. 1997; Kotliar and Wiens 1990; Pickett and Rogers 1997).

In contradistinction to patch–based approaches, gradient analysis conceptualizes landscape patterns and processes as continuous, clinal phenomena. In gradient analysis, variables are distributed across spatio–temporal continua. Thus, variation is observed and analyzed along dimensions of interest and the validity of spatio–temporal units such as patches is considered questionable.

Patch analysis, on the other hand, apportions landscapes into unitary patches or elements, each categorized according to one or more characteristics or statistical properties. Patches and configurations of patches are compared in terms of general dimensions such as absolute or proportional size, shape, connectivity, or clumpiness. Patch analysis deals with coagulated units and the spatial relationships between units or patches while gradient analysis deals with the variation across defined gradients in terms of smaller, less inclusive measurement samples or units. Landscape ecological studies tend to privilege patch–based approaches, despite the general merit and GIS–friendly characteristics of gradient analyses.

Sites as Patches and the Significance of Shape

Shape is an important dimension in landscape ecology. Patch shape is defined as “the form of an area (two–dimensional), as determined by variation in its margin or border” (Forman 1995:114). To Forman (1995), ecological patch shape is considered to be *morpho–genetic*, in that patch function can be predicted from patch shape. Empirical
studies of the relationship between landscape topography, human activity, and patch shape attributes conclude that attributes of patch shape can be predicted from variation in topography and the intensity of human activity (Forman 1995).

Patch elongation, measured as the ratio of length / width, results from unidirectional processes such as stream water flow, transportation, streamlined airflow, and glacial movement. Patch convolution, measured as the number of lobes, tends to increase with heterogeneity of spatial and temporal ecological processes. Shapes become less convoluted, or more rounded and smooth, when controlling processes are more homogeneous or evenly expressed. A village centering around a pivotal resource, for instance, may result in a more rounded patch, but if that village is tethered to a critical resources that is linear in shape (i.e. a river) the village patch will elongate along the critical resource (Forman 1995).

Patch elongation, convolution, shape diversity, and ecosystem diversity vary with changes in topography (plains, valleys, and slopes). Steeper, more topographically complex surfaces are associated with elongated, convoluted, diverse patch shapes and properties whereas more level, topographically homogenous surfaces are associated with more circular, simple, and homogeneous patch shapes. Patch shape is also affected by human activity. Moderate intensity human activity is associated with elongated, convoluted, and morphologically diverse patches, but high intensity human activity homogenizes and simplifies patch shapes (Forman 1995; Pietrzak 1989). Thus, the two-dimensional shape of ecological patches is partly determined by the morphology of earth surfaces and the intensity of human activity. From a landscape ecological perspective,
cultural design, landscape planning, and human environment interactions partially determine fundamental spatial and statistical properties of landscapes (Forman 1995; Haberl et al. 2004; Turner and Gardner 1991; Turner et al. 2001).

Sites as Patches

Patches are simply units with some common association or attribute. Foraging behavior can be modeled as taking place within the context of patches where targeted resources are potentially available. Much of the archaeological record may result from interactions with resources accessed within patches. Archaeological survey methodologies have incorporated ecological patches as survey units (Barton et al. 2004b). There is little reason, however, to assume that systemic patches attracting artifact-depositing behaviors are similar in form, content, or location to ecological patches observed in archaeological landscapes. Ecological landscapes are dynamic, changing under the influence multiple, interacting natural and cultural land–surface processes. As Stafford (1995:77) observes, the “probabilities that a landscape element will serve as a stopping point on the landscape (a place) may shift dramatically through time as the surrounding landscape changes.” Artifact deposition may preferentially occur within patches but landscapes elements or patches change in shape, size, and composition over time. Thus, the kinds of activities and associated artifact deposits attracted by particular patches may change along with changes in attributes of ecological patches. Attributes of ecological patches observed during the course of archaeological survey may vary dramatically from the past attributes of ecological patches in the same location.
Furthermore, the surface visibility of archaeological materials may result largely from the attributes of present ecological patches and bear little or no resemblance to past patch attributes that attracted artifact–depositing behaviors.

Theoretically, archaeological sites could be considered patches. If sites have properties similar to ecological patches, we can expect that site shapes will become more elongated and more convoluted on highly sloped areas and more compact and rounded (tending towards circularity) on areas of low slope. Patch orientation, fragmentation, and connectivity may also be affected by topography (Dorner et al. 2002). This variation in site shape, of course, would have little to do with systemic behaviors but instead results from variation in the topographic surface over which sites are draped. We might expect also that site shapes will vary with human activity. Behavior that defines, parcels, and carves up land surfaces as operative units should tend towards creating regularly shaped patches. Less organized behaviors, on the other hand, could reinforce shape complexity through nonlinear series of interactions.

Forman (1995) argues that patch shapes generated from human activity are easy to differentiate from natural patch shapes because human activity often results in geometric rather than amoeboid / curvilinear shapes. However, geometric patch shapes often result from agricultural, industrial, and residential activities of complex societies through the performances of formal landscape planning and design. That high intensity human activity is interpreted by landscape ecologists as producing geometric shapes may result from modern landscape interactions of highly complex societies and not be a general prediction for all human activity (lest the intensity of human–environment interactions)

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How the shapes of sites are defined in the field should have the greatest influence on site shape. That is, the techniques to measure and record site boundaries should have a considerable influence on site size and shape. Archaeological sites recorded with State Historic Preservation Offices are often amorphous blobs of varying size and orientation. In some cases, the elongation and orientation of sites appears to mirror the topography well, suggesting that variation in topography does affect the recording of site shapes. Site shapes are rarely defined to reflect the exact distribution of artifacts, sedimentary facies, or some other attribute. Often, they may be defined in terms of landforms. Thus, sites take on some aspects of the shape of land forms as perceived by investigators. Recorded site shapes are rarely convoluted, however, and perhaps are too coarsely defined to reflect complexity in the actual shape of the resource. Site shapes, as currently recorded, are too inconsistently and grossly defined to be considered as reliably reflecting some fine-grained, morphological properties of archaeological landscapes. Like many patterns in nature, the edges of archaeological artifact and feature distributions may be fractal, but the site sizes and shapes may be too coarse-grained to reflect those properties.

If we were to define site shapes to reflect transitions from high to low artifact densities, the shape of sites would probably be determined often by the shape of other landscape formations such as pedofacies, vegetation distributions, and hydrological resources. In other cases, site shapes might reflect land use: transportation routes, agricultural field boundaries, etc. In each case, however, site shape reflects how site
shape is defined and how those definitional criteria correspond to the shapes of features of the environment.

*Patch–Based Landscape Metrics*

In an attempt to quantify ecological landscape patterns, landscape ecologists have developed and, to a lesser degree, tested an extraordinary number of spatial metrics. These “landscape metrics” are formulated to identify and analyze variation in spatial patterns across landscapes and to interpret the relationship of observed patterns to spatial ecological processes. Most of these metrics are developed to handle data that are conceptualized according to a general model of ecological landscapes. That is, landscapes are mosaics of one or more classes of discrete patches. Metrics are thus designed to address spatial variation at three hierarchical levels: patch, class, and landscape.

Landscape ecologists are not entirely in agreement about the compositional structure of landscapes. Debate over the spatial composition of ecological landscapes parallels debates within archaeology over the nature of archaeological distributions or landscapes. Ecologists opposed to a pure, categorical “patch” concept explore or advocate analytical methods that erode the physical discreteness and categorical nature of patches. Opponents of the “patch” concept thus advocate methods that depend on smaller units of analysis (e.g., gradient analysis) or attempt to account for the fuzzy nature of patch boundaries (e.g., fuzzy logic).
One aspect of the usefulness of the patch concept is its analogy to the site concept in archaeology. As nice as it would be to obtain precise locational data for discrete artifacts and/or features over very large areas, such data requirements are often impractical. A common concern in the design of archaeological surveys is cost–effectiveness (Schiffer et al. 1978). Moreover, artifact–level distributional data are not the type of data that most land managers expect or care to incorporate into land management strategies. As a consequence, most of the spatial data archaeologists handle (that is not restricted to areas within defined sites) are not obtained objectively at the level of artifacts. Data that can be analyzed at the “landscape level” are generally confined to discrete polygons or points whose boundaries are defined at least partly according to subjective, judgmental criteria. Discarding the site concept entirely, as some authors have advocated (Dunnell 1992; Dunnell and Dancy 1983), is paramount to discarding an extraordinary amount of data (imperfect though it may be).

A potentially productive avenue of inquiry that accounts for some problems with the site concept and integrates analysis of site distributions with landscape ecology is to explore the treatment of sites as patches within archaeological landscapes. Are mosaics of sites similar to mosaics of ecological patches? Do spatial indices vary with scale when applied to site distributions (like they tend to do for ecological distributions)? Are site distributions across archaeological landscapes similar to ecological distributions on a purely spatial level? Do site distributions vary according to environmental contexts, technological organization, sampling procedures?
While these are all good questions, we can expect that the strongest influence on measured site distributions is sampling procedure. Measurement and representation of site boundaries are inherently subjective, unless derived from precise locational data obtained with smaller units of analysis. The shapes and sizes of sites on some level should vary with perceptions of surveyors as well as the methods used to detect, identify, and measure sites. The shape and sizes of sites as well as some aspects of their distribution may have a fairly strong stochastic component. Most sites officially recorded in AZSITE — a statewide relational database of sites recorded in Arizona — for instance, are blob–like in shape and maximize area with respect to perimeter. The recorded shapes of sites are simple and correspond to the perceived distribution of artifact densities exceeding a predetermined bureaucratically defined threshold. Recognizing the inherent fuzziness of site boundaries, attempts are rarely made to fit site boundaries around the “exact” artifact or feature distribution (which would likely result in a more convoluted boundary perimeter and thus a more complex, potentially fractal shape). While off–site data obtained for the IFNM survey — which recorded individual artifact and feature locations and attributes for offsite occurrences — testify to the performance of diverse activities or re–deposition of artifacts by natural processes across the landscape outside of recorded sites, the general spatial distribution of sites probably has some characteristics that are related, in a very general sense, to environment processes and/or technological behaviors.

Sites are often conceptualized, at least implicitly, as monolithic entities or discrete activity spaces. Archaeologists are quick to assume discrete functions for sites
(residential, resource processing, resource procurement) despite the diverse, multifactorial histories of site formation. Site formation processes are complex, involving many interacting variables. The potential complexity of site formation should encourage archaeologists to limit their \textit{a priori} assumptions about the functions of sites. At the very least, archaeologists should allow for a variety of plausible, testable hypotheses about the function of specific sites.

Ultimately, a site is a defined location or area where archaeological manifestations are concentrated. That a site is observed to exist is not interpretation–neutral. While some sites will have structure that makes interpretation of site geometry relatively straightforward (i.e., sites with sizes and shapes similar to those of known agricultural field types) the relationship between site shape and site function is not well known. Knowing where the site ends and the environment begins, however, is rarely rigorously explored, so site shape itself is not interpretation–neutral.

Even in cases where the spatial definition of sites is standardized, criteria used to define and measure site boundaries could be highly variable between projects, between sampling teams on the same project, between sampling methods, or according to local conditions. In many cases, a discrete boundary will be difficult to define. It may also be the case that archaeologists will tend to define sites according to existing natural features or landforms (assuming a relationship between archaeological manifestations and current environmental conditions). Archaeologists may also generalize site boundaries for a variety of reasons: 1) to limit assumptions about the exact extent of the distribution, 2) to limit time spent on boundary definition, 3) to produce smoother shapes. As a
consequence, site size and shape could vary most along dimensions introduced by methods of site detection, observation, and explanation. Site sizes, shapes, and distributions may have only very weak relationships with the processes we wish to study. They may simply convey the information that archaeological materials deemed to be of sufficient significance for recording exist in a general location.

Schiffer (1987) has argued that the behavior of archaeologists, in observing and interpreting archaeological manifestations, is the most significant factor influencing the archaeological record. That site shapes, sizes, and distributions are merely artifacts of the behavior of archaeologists, and not systemic behavior, is a worst case scenario. If this is the case, however, archaeologists need to innovate methods for describing archaeological landscape elements (which may or may not involve sites as units) and for examining archaeological spatial gradients according to methods that do not presuppose the existence or validity of sites as units.

An alternative, but not mutually exclusive, scenario is that site geometry and size distribution vary most according to natural processes. The most parsimonious explanation of site distributions could in some cases be the presence of surficial contexts that promote the trapping and display of artifacts and features. In such a scenario, sites could not be interpreted as having in their shapes, sizes, and distributions any necessary behavioral causes. In such cases, only relationships between other units of analysis (e.g., artifacts and features) could be used to formulate behavioral inferences. Such a scenario would not necessarily detract from the potential for predictive modeling of site location. Predictive models of site location could still work, but they would have to limit or
eliminate assumptions of relationships with systemic behaviors. Thus, the predictability or regularity of sites distributions could remain an important goal of archaeological research. At least we would still have an idea where concentrations of archaeological manifestations tend to be located.

The best-case scenario is that site distributions vary most according to human behavior. Although this assumption may form implicitly the foundation of many settlement pattern studies, the assumption is difficult to sustain. Do we know that site distributions possess a strong behavioral signal? Many factors have to be controlled before such an assumption is warranted. Controlling for these factors is no trivial task and often requires the application of numerous, related environmental investigations.

_Distributional Archaeology_

Archaeologists have long conceptualized archaeological phenomena in terms of sites, themselves composed of smaller units such as artifacts and/or features. David Thomas was an early practitioner of “siteless” survey and more recently, the concept and applicability of sites as monolithic units has been questioned on a number of fronts. In place of sites, archaeologists have suggested distributions or gradients of artifacts and features more accurately reflect spatial and temporal variation in _archaeological landscapes_.

The underlying basis for the distributional approach is the inadequacy and possible fallacy of sites as units of observation and analysis (Dunnell 1992; Ebert 1992). Rossignol (1992:9) sums up the potential problems associated with an "overdependence
on the site concept" as: "(a) the neglect of dispersed 'off-site' materials that are important for investigating land use at the regional scale, (b) inexact or vague definitions at the observational level, making data collection and statistical analysis difficult, and (c) a tendency to treat sites as monolithic entities, underestimating the complexity of occupation–component interaction." Other authors (Banning 2002; Binford 1992) have noted that sites retain validity as units of observation and analysis and should not be entirely discarded. Despite the argued strengths of distributional approaches, sites are not likely to disappear as units of analysis for some time to come.

In the interests of pragmatism, convention, and convenience, archaeologists have generally remained faithful to the site concept. The site concept is comfortable, relatively easy to understand, and confines measurements and observations to a bounded (though subjectively defined) two or three–dimensional space. Sites are mentioned in federal laws and regulations. The site concept also provides discrete, bureaucratic units for land management. At very broad scales of analysis, use of sites as analytical units is not necessarily problematic as site size approaches analytical grain size (the size of the smallest mapping unit used in analysis). However, the size and shape of sites are often arrived at intuitively and are thus highly variable not only as a result of behavioral and environmental processes but as a result of investigative procedures (sensu Schiffer 1987).

The case for distributional archaeology does have some strong selling points. Distributional archaeology advocates a more objective approach to sampling and generating data on archaeological landscapes. As Ebert (1992) observes, when sites are entirely removed from consideration, archaeological distributions appear far more
continuous than discontinuous. Clustering emerges and varies according to spatial extents, grain sizes, and variables of interest. Some of these patterns of clustering, or aggregation, may be related to fundamental properties of landscapes (e.g., geomorphological landscape elements) that themselves may be related to the scales of either environmental or behavioral processes or patterns. For instance, Ebert (1992) finds that quartzite debitage and relatively informal flake tools tend to organize over large spatial extents on alluvial terraces, but at smaller spatial extents for other geomorphological units (e.g., dunes, mesas). Ebert (1992) suggests that this may be because quartzite cobble distributions occur in areas of alluvial terraces at large spatial extents (an intuitively satisfying inference).

The supplanting of site–based approaches with distributional approaches, however, does not eliminate the problem of *ad hoc* forms of interpretation and explanation. Positing some sort of relationship with any old environmental or behavioral process or pattern without developing models that incorporate variation across these dimensions remains a problem. What is needed for distributional archaeology to succeed is a complimentary body of theory that can explain how different kinds of artifact–based archaeological landscape patterns are generated from systemic landscape interactions and at what scales such patterns should be expected.

Distributional archaeology, in its accumulation of very fine–grained data, permits analysis of patterns at many different scales. With fine–grained data, data can be “upscaled” so as to identify appropriate ranges of scales at which relevant patterns or processes exist. It is very difficult, and perhaps entirely unjustified, to go in the other
direction. One cannot very easily “downscale” data obtained at coarse resolutions (at least without an excellent understanding of how patterns are related across scales). However, given the intensive data requirements of distributional archaeology, the absolute spatial extent of sampled units cannot be very large, surface artifact densities must be low on average, and measurement instrument visibility must be high (in cases where total station mapping is required). Thus, spatial and survey technological constraints are limiting factors for the implementation of distributional approaches.

**Distributional Archaeology and the Coverage Problem**

It has been relatively well demonstrated in landscape ecology that changes in the size of the study area exert some of the most dramatic effects upon spatial metrics (Wu 2004). This is largely because increasing the extent of a spatial window (study area) increases the chance that new patterns not represented by smaller spatial extents will appear (Plog, Plog, and Wait 1978). The sample size / diversity relationship investigated in biogeography, archaeology, ecology and other fields probably plays a significant role here.

When the spatial extent of a landscape window increases we can expect two things to occur: 1) broad–scale spatial patterns have a higher probability of appearing, 2) higher diversity of fine–scale and meso–scale spatial patterns have a higher probability of appearing. While *large numbers of small samples* may uncover a broader range of fine–scale patterns, such samples may not reveal, or even obscure, broad–scale patterns (unless patterns at varying scales can be predicted by fractal dimensions).
If research questions are directed at spatial structure of settlement systems, then units may need to be as large or larger than the extent of human settlement systems to capture relevant patterns. The ability of large units to reveal patterns of large extent is at least one argument for so-called “full-coverage” survey (Fish and Kowaleski 1990). While full-coverage survey is itself a sampling method (defined by intensity not sample size per se), it does have the potential for revealing patterns of large extent (i.e., community structure, interacting use of broad resource zones, behavioral variation according to environmental processes of large spatial extent [i.e. erosion regimes]) (Kintigh 1990; Kvamme 1998).

**Practical Limitations of Distributional Archaeology**

The intensive data requirements and practical field limitations of distributional archaeology are perhaps the major reasons that the approach has not been widely adopted. While Ebert (1992) argues that the approach is more doable (less expensive) than it seems, the practicality of applying truly distributional approaches is a matter of local and regional archaeological conditions. In the Seedskadee National Wildlife Refuge distributional survey in the Green River Basin of southwestern Wyoming (Ebert 1992), for instance, lithics appear to have been the only artifact class observed. No ceramics were observed and densities of lithic artifacts were often less than 1.0 artifacts / m². Since the area is thought to have been prehistorically utilized only by foraging populations, the lack of artifact classes such as ceramics and the generally continuous distribution of artifacts are not entirely unexpected. In the IFNM survey, offsite artifact
densities across sampled areas tended to also fall below 1.0 artifacts / m$^2$. Randomly sampled onsite artifact densities, on the other hand, averaged 1.87 artifacts / m$^2$ and the maximum density recorded for the IFNM survey was 15 times larger (28 artifacts / m$^2$).

In the Mediterranean and Near East, offsite ceramic artifacts can be so dense that they form a virtual carpet, far exceeding any rationale for recording individual artifacts across broad areas (Bintliff and Snodgrass 1988; Wilkinson 1994). Excepting unusually sparse, open contexts where piece–plotting individual artifacts across broad archaeological landscapes is feasible, alternative methods for measuring distributions of archaeological materials will have to be developed. In order to obtain measures of offsite artifact density, field projects have in some cases employed the use of tickers to count artifacts along sample transects. Increasingly precise GPS equipment, also, may allow field projects to objectively obtain artifact–level data over broad areas at relatively low cost.
CHAPTER IV —SCALE IN LANDSCAPE ARCHAEOLOGY

In this chapter, I address the critical issue of scale in landscape archaeology. I argue that issues of scale are important at every level of observation and analysis and outline some issues of scale along temporal, spatial, and social dimensions. In attempting to answer the basic question – How big is a landscape? – I juxtapose human systems against ecological frames of reference. Drawing further on research in physiology and ecology, I advance the notion of landscape allometry. I present the working hypothesis that, like biological and ecological systems, basic properties of systemic and archaeological landscapes may be allometrically related. I envision the potential for these “scale–invariant” relationships to enable investigation of landscapes across broad ranges of scales, relate fine–scale processes to large–scale patterns, and illuminate how basic properties of landscapes are interrelated.

Scale, heterogeneity (or diversity), and spatio–temporal systematics are issues fundamental to the development of landscape archaeology. When archaeologists use the term “landscape,” they are often referring in some way to issues of scale. They mean to say something like, “the total environment that encompasses or realizes the processes and patterns under investigation.” Landscape analysis typically involves a shift in perspective from analysis of one or a few examples of a particular class of archaeological scientific objects (i.e., sites) to analysis of more continuous distributions of classes or class dimensions across time and space. Very generally, a landscape is a broad–scale array that is heterogeneous according to one or more spatial and / or temporal variables.
Many different kinds of scale are relevant to archaeological research. In a very general sense, archaeological patterns and processes are used to infer systemic patterns and processes arrayed according to three scales: *spatial, temporal, and social*. Recall that behavioral archaeologists recognize a hierarchy of behavioral scales: *interaction scale, activity scale, and systemic scale* (LaMotta and Schiffer 2001). A basic issue in archaeology is the relationship between the spatial, temporal, and social scales of analytical units and the scales of behavioral and environmental patterns and processes. In many cases scales of observation and analysis can be quantified, but their relationship to the scale of systemic patterns and processes of interest is largely unknown.

*Social Scale*

Archaeological phenomena relate to systemic phenomena occurring at a wide range of social scales. While recent years have seen much attention paid to concepts such as agency (Hodder 1986; Tilley 1981), the thoughts, perceptions, and actions of individuals are difficult to extract from archaeological evidence, though not perhaps impossible. The formation of a single flake likely results from the action of an individual, but many flakes on an archaeological surface could result from the actions of an individual, a household, a task group, many isolated individuals, etc. Moreover, these could be produced during a single episode or many related or disconnected episodes of artifact manufacture, use, maintenance, and discard. Detailed analysis could tease apart some of these variables but most often we have to treat cultural deposits as aggregates of behavior.
Like temporal and spatial scales, social scales can be considered in a hierarchical fashion. A scalar hierarchy composed of residentially–based units might specify that households are composed of individuals, communities of households, regional systems are composed of communities, etc. Different kinds of non–residential social units — such as ceremonial organizations, trading networks, mating systems, and bureaucracies — can also be composed of or constitute other kinds of hierarchically scaled units. Different kinds of processes may operate at different social scales, and thus different models might be required for differently scaled phenomena. Identifying any of these social units in the archaeological record is notoriously difficult. Nonetheless, the social scale to which systemic processes and archaeological patterns pertain remains an important avenue of archaeological inquiry (Deetz 1982; Downum 1993; Fish et al. 1992; Holl 1993; Kramer 1982).

An interesting aspect of complexity theory is the idea that fine–scale strategic decisions (i.e. the decisions of individuals, households, administrative units) can generate complex ordered patterns at larger social scales (Lansing 1991, 2003). Thus, while we must take into account differential processes, behaviors, and levels of detail occurring at different social scales, we should also consider how different scales of behavior might be interrelated. Indeed, the fundamental, irreducible component of social networks – upon which social constructions such as households, corporate groups, or communities are based – is the agent (Thomas 2000). While agents do not contain within them the entirety of the behavioral systems within which they operate, the actions of a single
individual – when poised at a critical threshold – can precipitate earth-shattering events of completely unpredictable magnitude and complexity (Buchanan 2002; Watts 2002a).

Temporal Scale

There are a great many issues relevant to temporal dimensions in archaeological research. I do not intend to review these here, but only to present a brief summary of chronological issues so as to outline their relevance to issues of scale in landscape archaeological studies.

Chronologies are crucial components of archaeological research. Archaeologists have long been preoccupied with establishing chronological control over investigated patterns and processes. A major distinction archaeologists make is between absolute and relative chronologies. Absolute dating techniques (i.e. dendrochronology, calendrics) allow archaeologists to estimate target dates of archaeological patterns and materials according to a fixed, absolute temporal scale. Absolute dating techniques vary according to temporal resolution (probable range of dates for a given measurement) and temporal range (time period over which a given absolute dating technique can be applied), as well as materials and contexts appropriate for the application of different methods. Relative dating techniques (i.e. stratigraphic superposition, seriation, cross-dating) allow only for the relative positioning of archaeological patterns and materials with respect to each other along a relative time scale (Haury 1955; O'Brien and Lyman 1999).

Relatively dated archaeological patterns and materials can be anchored by absolute dates or date ranges. Archaeologists will often use a combination of relative and
absolute dating techniques to establish chronological control, resulting in the relative ordering of archaeological patterns and materials according to general phases or periods bounded by absolute dates or date ranges. As there is often an inconsistent or ambiguous match between dated materials and target dates, chronological control can only be reliably established through careful inference (Dean 1978).

In general, temporal scale refers to the time frame represented by a pattern or process. Many behavioral processes observed ethnographically or ethnoarchaeologically occur at brief time scales. In contrast, the chronological resolution of many studied archaeological patterns is coarse, often transcending the length of human generations, individual life spans, community life spans, or even behavioral systems. It may often be the case that problems archaeologists are interested in occur at time scales too brief to be accessed by available dating methods or appropriately resolved in archaeological contexts. Due to the problems of chronological control, the most reliable statements about the past are often pertain to the long durée: long–term trends, highly persistent behavioral systems, or behavioral meta–systems.

Establishing chronological control is a major concern in site–based investigation. The problem of chronological control can only be magnified with the study of landscapes. Many landscape studies obtain chronological information primarily from surface contexts (Stafford 1994, 1995; Stafford and Hajic 1992) and thus lack relevant contextual data for establishing chronological control. In recent years, a number of researchers have attempted to address temporal dimensions in archaeological landscapes (Barton et al. 2004a; Wandsnider 2004). Barton et al. (2004), for instance, devise a
temporal index for survey data from eight study areas in the Alicante Province of Eastern Spain that uses presence/absence of diagnostic tool types to estimate the probability that a certain time period is represented in a given locale. When used in combination with indices of settlement intensity (derived from estimated artifact densities and accumulation rates), the use of a temporal index allows the authors to estimate the overall extent of land use and land use intensity during different time periods (Barton et al. 2004a). The issue of establishing chronological control for landscape–level data still requires much additional methodological experimentation and research.

One way to establish chronological control of landscape–level data is to infer the stability and relative or absolute ages of landscape surfaces using a combination of surface and subsurface sampling techniques, geochronological and geomorphological inferences, temporally diagnostic artifact and feature attributes, and evidence of weathering processes. Establishing these multiple lines of temporal evidence can be an enormously complicated task, requiring multidisciplinary investigations and the establishment of temporal relationships between many different kinds of data points (e.g., Hayden 1976a, 1976b, 1998).

Like spatial processes, temporal processes operate at a variety of different scales and it is important to understand how these scales integrate with scales of human information processing and decision making. Gumerman and Dean (1989) for example differentiate between low–frequency processes and high–frequency temporal processes in order to explain the relationship between environmental variation and behavioral change. Low–frequency processes vary meaningfully over periods longer than a human
generation whereas high frequency processes vary meaningfully over periods considerably less than a human generation. Despite the fact that fine-grained, individual responses to environmental variation likely integrate information on high (rather than low) frequency processes, the authors argue that low frequency “environmental variability seems to have had the greatest impact on human adaptive behavior” (Gumerman and Dean 1989). Indeed, century-scale climatic fluctuations (i.e., the Little Ice Age and the Medieval Warm Period) occurring as sequences of decadal and subdecadal variations have produced some of the more recognizable climatic impacts on behavioral change (Grove 1996).

Hill (2004) argues that temporal hierarchy requires that different explanatory models are necessary for different temporal scales. Since small and large scale temporal processes may have different causes, “large-scale processes cannot be reduced to the small scale, and small scale processes are not determined by the large scale” (Hill 2004). Although I agree that different models are certainly required for different kinds of processes, it may be excessively particularistic to dictate that deterministic relationships do not exist between different levels of temporal hierarchy. As Corning (1998) argues, a major challenge for science today is the integrated modeling of relationships between processes occurring at a variety of scales.

*Landscape Temporality and the Sierra Piñacate*

Julian Hayden pioneered the modeling of landscape formation processes and chronological inference-building in desert pavement landscape contexts of the Sierra
Piñacate. Although his basic conclusions regarding the time depth of Sierra Piñacate archaeology have yet to be fully supported, his general inferential methodology should be of interest to current practitioners of landscape archaeology, for the chronological problem Hayden faced is the same kind of chronological problem faced by landscape archaeologists today. How do we establish chronological control for artifacts, features, and site components from surface contexts?

Through a variety of methods that combined multiple lines of evidence the details of which are described in Heilen (2001, 2004), Hayden was able to establish the relative chronologies of artifacts, features, site components, and landscape surfaces. Whenever possible, Hayden anchored these relative chronologies to chronometric dates obtained from related geochronological and climatological data. He was thus able to infer the relative and absolute amount of time available for landscape surfaces to receive behavioral inputs (artifacts and anthropogenic disturbance processes) and to establish relative and absolute temporal relationships for archaeologically observed surface patterns (Hayden 1965, 1967, 1976a, 1976b, 1998; Heilen 2001, 2004). At the time, he and Malcolm Rogers were probably the only archaeologists using landscape–level evidence to make reliable inferences about the temporality of surficial archaeological contexts (Hayden 1961, 1994; Rogers 1939, 1945, 1958, 1966). That it took Hayden several decades to complete this research attests to the enormous complexity and difficulty of the task (Heilen 2001, 2004).
Temporality and the Tucson Basin

Despite its inherent difficulty, establishing the temporality of archaeological landscape patterns is crucial to building inferences about land use and settlement patterns. As has been shown for the Tucson Basin, Holocene episodes of erosion and deposition account for the differential exposure and erasure of sediments of different ages. The paucity of evidence for Paleoindian land use in the Tucson Basin cannot be used to argue the absence of Paleoindian activities in the area. Rather, broad scale, mid–Holocene, post–Paleoindian erosion has removed many sediments of the appropriate age and has thus erased any evidence that may have existed (Waters 1988). Indeed, while the best–studied Paleoindian sites in Arizona are confined to the San Pedro Valley (Haury 1953, 1956; Haynes 1981, 1982), isolated finds of Paleoindian age (n = 36) are scattered across other areas of Arizona including the Tucson Basin and adjacent valley systems (Faught and Freeman 1998). From this example we can hypothesize that the temporality of broadly scaled landscape formation processes (i.e. cycles of erosion and deposition) partly determines the archaeological visibility of different archaeological time periods (Schiffer 1987).

Further, geologic architecture of the southern basin–and–range province ensures generally deep deposition of eroded and transported sediments along valley axes (Ahlstrom 2000). Early agricultural behaviors during the Late Archaic have gone largely unrecognized until recently simply because researchers lacked the time, funding, or imperative to dig deep enough into alluvial sediments. In the Middle Santa Cruz Valley, for instance, uncharacteristically deep excavations conducted within the last decade
revealed the unanticipated presence of deeply buried early village sites argued to require rethinking of regional prehistory and the timing of agricultural development and residential sedentism (Mabry 1998).

The artifact density of archaeological surface deposits is a function of both natural sedimentation rates and cultural rates of artifact deposition and removal. In order to interpret variation in surface artifact densities, archaeologists need to model spatial variation in the rates of deposition and erosion relative to rates of cultural deposition (Schiffer 1987). Due to relatively high sedimentation rates, alluvial surface deposits along major valley axes in the southern basin–and–range province should generally be biased towards later periods. Contrastively, higher elevation environments (i.e., upper bajada) that have experienced deflation or minimal deposition during the Holocene should exhibit a chronologically wider range of diagnostics at the surface. Such surface deposits, however, are likely to compress archaeological materials from many different time periods into a complex palimpsest. In landscape contexts where sediments of varying geological ages are differentially exposed, spatio–temporal distributions of artifacts, features, and sites may say a lot more about natural landscape formation processes than about temporal change in land use and settlement systems.

In order to study land use and settlement patterns it is essential that we control for earth surface processes affecting the storage, erasure, exposure, and burial of archaeological materials. Although these effects may be commonly understood to occur, attempts to control for them in settlement pattern studies are rare. In truth, without
substantial interdisciplinary investment in geological survey, controlling for earth surface processes may be difficult to achieve.

In the IFNM, for instance, geological data on surface sediments is available from the Arizona Geological Society. Many surfaces are assigned to general time frames (i.e., Early, Middle, or Late Pleistocene; Early, Middle, or Late Holocene; Recent), but most of the archaeological materials that are diagnostic to time periods can be squeezed into one or two of the geologically assigned time periods (i.e., Late Holocene). The few projectile points that may be Early or Middle Archaic in age were found on older, Pleistocene surfaces, but these are probably too few in number to make a strong case that older materials are associated with geologically older surfaces. In short, the temporal (and spatial) resolution of the geological surface data is probably too coarse to be useful in statistically monitoring the relationship between the ages of archaeological materials and the age of landscape surfaces.

This does not mean that such relationships do not exist. It is probably no accident that the densest and most diverse occurrences of archaeological materials occur in IFNM samples dominated by older Pleistocene surface sediments in upper bajada settings. It is probably also no accident that a middle Archaic projectile point was found on a small, remnant Pleistocene terrace surrounded by Holocene alluvium otherwise dominated by late Prehistoric Hohokam ceramics. Neither is it an accident that very few prehistoric artifacts were observed for some samples in the Aguirre Valley, where many modern migrant materials — items lost or discarded by undocumented immigrants while traveling through the IFNM — are already partially buried by sheet wash sediments.
That temporal diagnostics from similar samples tend to be historic or modern in age certainly means that these land surfaces have been used historically and in modern times, but it also does not mean an absence of human activity during earlier time periods.

Spatial Scale

Landscape scientists investigate spatially distributed processes at a variety of scales. Recent publications in ecology attest that the effects of scale on ecological patterns and processes are a major preoccupation in current ecological practice (Gardner et al. 2001; Seuront and Strutton 2004). Spatial scale can be defined in terms of two components: grain and extent (Turner and Gardner 1991; Turner et al. 2001; Wu and Qi 2000). Grain refers to the smallest mappable unit, or resolution, of a landscape dataset. For instance, a raster grid composed of 30 x 30 m cells has a grain size of 30 meters. Decreasing the grain size (to say 10 x 10 m) increases the spatial resolution of the data set. Extent refers to the absolute size of a landscape dataset. In landscape ecology, a square landscape measuring 1000 x 1000 meters is generally reported as having an extent of 1000 meters. The convention is to report the representative linear dimension of two-dimensional units, rather than a composite measure such as area (Figure 4.1). For archaeological study areas, many of irregular shape, reporting extent in one dimension is inappropriate. For irregularly shaped landscapes area should be used to represent extent or grain.

Changes in scale have significant effects on most spatial and temporal patterns and processes. A major problem in comparing the results of different studies results from
**Figure 4.1** A raster (grid) landscape of arbitrary grain and extent. Extent and grain are conventionally reported as representative linear dimensions of areal units.

The lack of equivalency between scales of analysis in different studies. The lack of scalar equivalency could be a problem of differences in either the grain or extent of compared studies (or both). Contradictions between the results of different studies can be methodological artifacts of variation in scales of observation and analysis (Guest 2003). However, changes in patterns and processes resulting from changes in scale can also relate to shifts from one hierarchical level of patterns and processes to another (Wu and Qi 2000).

General expectations for scale effects differ for changes in grain or extent. As grain size decreases, the amount of spatial detail (and potential variance) increases. Many landscape metrics, such as patch density, landscape shape index, and patch size
variance, vary indirectly with changes in grain size. An exception to the rule is a metric like mean patch size, which necessarily increases as an artifact of increased grain size. Increases in extent result in increased variance in landscape properties (Figure 4.2). Landscape metrics tend to vary directly with changes in extent (Gardner et al. 2001; Kemp et al. 2001; Wiens 1989; Wu 2004).

Wu (2004) analyzed the effect of varying grain and extent on 21 landscape metrics for three different landscapes (i.e. patch richness, total edge, number of patches, area–weighted mean fractal dimension). For most of the metrics analyzed, changes in grain or extent resulted in different kinds of scaling relations: power law, linear, logarithmic, staircase, unpredictable, other. Changing grain (while holding extent constant) results in predictable scaling relations for 84% of studied metrics and over half of these are power law relations. In contrast, changing extent results in predictable
scaling relations for only 57% of studied metrics, and almost half of these are staircase scaling relations (Figure 4.3).

Figure 4.3 Comparison of types of scaling relations obtained by Wu (2004) on 19 landscape–level metrics.

Landscape Extent

When anthropologists think of landscape, it is likely that they are thinking of something that is very large. Perhaps they are thinking of an area that is far larger than a single site and smaller than a major region. Perhaps they are thinking of the total area accessed by an individual or a household over the course of a year or even a lifetime. Perhaps they are thinking of a general land area that encompasses the totality of environmental resources that support or define the economic and cultural activities of a
particular ethnic group or ecological population. Perhaps anthropologists are thinking of landscape as a hierarchical level above site and below region. Anthropologists are likely thinking of a large area over which a variety of related social, technological, economic, and environmental processes take place.

From a landscape ecological perspective, landscapes have no necessary absolute dimensions. Landscapes can be measured in tens of meters or in thousands of kilometers. The size of a landscape is constrained by the scale of investigated processes (and by the sponsors who pay for the project). If we are interested in behavioral processes, the size of a landscape can be defined according to the spatial scale at which given behaviors occur. Thus, anthropological landscapes vary in size according to the scale of behavioral processes. Organisms that operate at fine spatial scales perform behaviors that are heterogeneously arrayed across landscapes of limited extent. Organisms that operate at broad spatial scales perform behaviors that are heterogeneously arrayed across landscapes of broad extent (O'Neill et al. 1988; Ritchie 1998).

A major problem with studying spatially explicit behavioral processes is identifying the spatial and temporal scales at which targeted behaviors occur. As of yet, we have no well developed methods for identifying and defining spatio–temporal scales of behavior. Plus, the relevant scales will vary by the behavior and by the group. Consequently, we have no objective methods for defining the appropriate scale of humanized landscapes. Environmental scientists interested in landscapes emphasize the use of multi–scale or scalar approaches, stressing that targeted variables be examined at a
variety of scales. Multi–scale landscape investigations often uncover scale effects – changes in scale often result in changes in landscape metrics.

Scale effects are nontrivial. Multi–scale investigations are comparatively rare in archaeology (Ebert 1992; Premo 2004), but are nonetheless important for identifying the scales over which investigated processes occur as well as identifying how analytical results will change with scale. Investigation of a process at different scales may often provide disparate results. The lack of congruity in scales of investigation between projects may often result in incongruous results. Valid comparison of different projects thus is dependent on accounting for differences in scale.

From a purely theoretical and very general perspective, landscapes should have no absolute constraints on their minimum and maximum sizes. Both intuitively and objectively, however, we know that human landscapes cannot be of the same size ranges as those of say micro–organisms or tiny insects or as big as those important to the formation of continents, planets, stars, and galaxies. Human landscapes (at least those we are accustomed to think about) must be large enough to accommodate the spatio–temporal dynamics of human behavioral systems – from tens of square kilometers to tens of thousands or hundreds of thousands of square kilometers. Analytically, human systemic landscapes must be at least as large as the spatial components of processes hypothesized to create them.

People can move and interact over huge territories, but even for foragers and collectors the range of variation is large. The total area in which ethnographically observed residential moves of foragers and collectors take place, for instance, can range
by four orders of magnitude (0.3 to 619 km$^2$). The physical area in which residential
moves are observed to occur on short ethnographic time scales is obviously far smaller
than the total area over which many systemic behaviors take place (Kelly 1995). If we
are to think of landscapes as territory, the “Nunamiut maintained knowledge of nearly
250,000 square kilometers (Binford 1983); the Australian Pintupi have knowledge of
over 52,000 square kilometers (Long 1971)” (Kelly 1995). If we are to consider the
entire range of human adaptive systems (from small foraging populations, to middle
range agricultural societies, to highly complex modern nation states), the range of
variability in human systemic land use is probably enormous. Imagine the spatial extent
of a multinational corporation! Just as village agriculturalists might remain tethered to
relatively small settlement districts or migrate hundreds of kilometers, individuals in
modern, urbanized nation–states might confine most of their activities to small, urban
neighborhoods or they might regularly travel extensively across vast territories.

If we juxtapose human landscapes against ecological frames of reference, we
cannot account for the tremendous variability in human land use and mobility, but we can
get a sense of the amount of area used by similarly size organisms. Body size for
herbivores, carnivores, and omnivores may scale allometrically with home range, but
sampling bias and recordation techniques could account for the allometric appearance of
a possibly linear or isometric relationship (Lindstedt et al. 1986). Ultimately, the size of
an organism’s home range depends on energetic requirements (Table 4.1). Home range
size thus depends on how organisms obtain energy and the spatial allocation of energetic
resources. The home range of polar bears, for instance, is far larger than expected from
allometric predictions because of spatial and temporal variation in the availability of crucial resources, such as seals (Ferguson et al. 1999). Similarly, high latitude carnivores (> 45 degree latitude) tend to have home ranges ~ 5 times larger than lower latitude carnivores (Lindstedt et al. 1986). Home range size is thus a “a function of the structure of the environment” (Haskell et al. 2002:528) and “for a given body mass, home range can vary widely depending on environmental conditions, locomotory capacity and resource density” (Haskell et al. 2002:528-9).

The home range sizes of humans should vary according to similar variables, depending both on how people get food and how food resources are spatially distributed. If techno–ecological strategies enable humans to occupy niches with spatial attributes similar to those of nonhuman carnivores, herbivores, and omnivores, the home range of individual humans could vary between 1.5 km$^2$ to 300 km$^2$ (Table 4.1). Excepting some highly urbanized societies, where individuals can obtain most resources locally from distant sources through corporate transportation mechanisms, human home range size is probably more often closer to that of carnivores. Human home ranges on the order of those of herbivores and omnivores probably require food production (as opposed to collection) strategies as well as different technologies and infrastructure for extracting and circulating resources between nodes in landscape networks. Thus, landscapes of individual human experience may be on the order of $10^0$ to $10^3$ km$^2$, a range that is roughly consistent with the observed range of area over which ethnographically observed residential moves take place (Binford 2001; Kelly 1995).
Table 4.1  Comparison of home range sizes for human–sized organisms according to eating habits and latitude.  Home ranges calculated from equations in Lindstedt (1986).

<table>
<thead>
<tr>
<th></th>
<th>Home Range (km$^2$)</th>
<th>Body Size (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>carnivores, all</td>
<td>121.3</td>
<td>63</td>
</tr>
<tr>
<td>carnivores, ≤ 45 latitude</td>
<td>56.5</td>
<td>63</td>
</tr>
<tr>
<td>carnivores, &gt; 45 latitude</td>
<td>297.5</td>
<td>63</td>
</tr>
<tr>
<td>herbivores</td>
<td>1.9</td>
<td>63</td>
</tr>
<tr>
<td>omnivores</td>
<td>1.5</td>
<td>63</td>
</tr>
</tbody>
</table>

If we are to equate the amount of area necessary to sustain a viable population of human–sized organisms, human reproductive landscapes are larger still. Maximum and minimum body size of mammals on islands and continents scale allometrically with landmass area. Body sizes similar to humans appear as maximum body sizes in body size distributions once land area is in the range of 15,000 km$^2$ to 63,000 km$^2$ (Brown et al. 1993). This suggests that populations of organisms within the same size class as humans require access to land areas on the order of $10^4$ km$^2$ or larger to remain viable.

If we instead look at the relationships between body size and geographic range — the area over which a particular adaptation or species is distributed — we find that human–sized organisms occupy geographic ranges on the order of $10^5$ to $10^7$ km$^2$ (Brown and Nicoletto 1991). Of course, the geographic range of humans is far larger, encompassing most areas of the globe, largely because humans are so versatile. Adaptations or “culture areas” — the areas over which important, fundamental techno–environmental human adaptations occur — might be similar in size to geographic ranges of human–sized organisms. However, we should also consider them to vary greatly
because of broad variation in the methods and rates by which humans extract energy from their environments.

In terms of conventional archaeological units of analysis, archaeological landscapes are positioned hierarchically above the units of which they consist – artifacts, features, sites. In such a scheme, landscapes might be interposed hierarchically somewhere between sites and regions. It is quite possible, however, for landscapes to transcend the size of conventional archaeological regions or culture areas depending on the scales of patterns and processes under investigation.

Similarly, we might consider systemic landscapes to occur at the scale of individual valley systems, bounded physio–geographic territories, critical resource distributions, breeding populations, or environmental regimes. The scale of any of these landscape units or arrays could cover a very wide range of spatial extents. For instance, we might consider historic frontier ranching phenomena to be realized within a nested hierarchy of interrelated physical and cultural landscapes – local valley systems (i.e., Cienega Creek Valley, San Pedro Valley, Santa Cruz valley), encompassing physio–geographic areas or centers of localized, political, economic, and cultural activity (i.e., southeastern Arizona), expanding regional frontiers (i.e., the American Southwest or the larger American West), the territories of large nation–states (i.e., the United States of the late 19th century), or even landscapes occurring at international, continental, or transcontinental scales (Heilen and Reid n.d.).

The definition of landscape size or shape is thus process– and problem–oriented. Landscape analysis could consider a single arbitrarily or organically defined landscape,
multiple discrete landscapes of similar or disparate shapes and sizes occurring in similar or disparate cultural, historical, or environmental contexts, or multiple, hierarchically nested landscapes in which landscape patterns and processes interact across a range of local, intermediate, and global scales. The size or extent of a landscape and the detail or grain in which it is perceived is fundamentally related to energetic, material, and spatial requirements of ecological behaviors. Nation states that absorb frontier resources need to organize and interact with exploitable resources at scales consistent with the energetic and material requirements of national maintenance and expansion. Similarly, foragers relying on highly mobile resources need to pay attention only to as much environmental detail as necessary to exploit their prey and mate. Agriculturalists need to have intimate, detailed knowledge of the physical and cultural systems contributing to the successful operation of their field, storage, and residential complexes, but less detailed knowledge of broader, encompassing environments or regions. In essence, humans scale their behaviors and perceptions to the characteristics of the food–getting (energy–absorbing) systems with which they integrate. Thus, the size of a behavioral ecological landscape is scaled according to spatial grain and extent of exploitable resources and the scale of human techno–ecological networks required to circulate resources through activities for physical maintenance and reproduction.

**Landscape Allometry**

Allometry is a concept familiar to biology and physiology (Peters 1983). In contrast to isometry, allometry means that one component of a relationship changes scale
at a different rate than a related component. Although allometric relationships have long been recognized in biology and physiology, an explanation for their wide occurrence has evaded investigators. More recently, allometric relationships have been explained as emergent properties of network systems. Allometric relationships are expected to occur commonly in metrics that reflect the structure and function of network systems.

Allometric relationships take the form of the equation, where $k$ is the *allometric growth ratio*, and $b$ is an empirical constant, $y$ is a variable (such as rate) whose scale depends on $x$ (i.e. body mass):

$$\text{Eq. 4.2} \quad y = b x^k$$

Due to their mathematical form, allometric relationships are also referred to as power law relationships. Allometric relationships appear as straight lines on log–log plots, and thus allometric relationships can be obtained by linear regression of log–log data, resulting in the following formula:

$$\text{Eq. 4.3} \quad \log y = \log b + k \log x$$

When $k = 1$, both $x$ and $y$ components grow at an equal rate and are hence *isometric*. Allometric relationships occur when $k \neq 1$. When $k > 1$, $x$ components grow at a faster rate than $y$ components (*hyperallometry*). When $k < 1$, $y$ components grow at a greater rate than $x$ components (*hypoallometry*). Allometry is closely related to fractal
geometry as both are mathematically represented by a power law function. In the case of fractal geometry, k (in the above equation) is related to the fractal dimension.

Allometric relationships in biology have some astoundingly regular properties. When standardized according to environmental temperature, metabolic rates of organisms (W) scale as mass (M) to the \( \frac{3}{4} \) power across a huge range of body sizes. Despite tremendous variation in functional characteristics and heredity, this single power law relationship applies to mammals, birds, reptiles, fish, amphibians, invertebrates, plants, and unicellular organisms. One common scaling relation encompasses 27 orders of magnitude and “integrates power production across all levels of biological organization”: enzyme molecules, intact mitochondria, unicells, and multicellular organisms (Gillooly et al. 2001; West et al. 2002).

Many other biological rates (e.g., heart rate, reproductive rate, cellular metabolic rate) scale as mass to the \(- \frac{1}{4}\) power (Moses and Brown 2003; Peters 1983; West et al. 1997, 1999). These scaling relations apply equally to plants and animals because they are likely derived from the properties of fractal–like metabolic or energy–transporting networks (i.e., blood vessels). Quarter power scaling of “many attributes of organic structure and function” is predicted by theoretical modeling of fractal networks (Niklas and Enquist 2001). Fractal scaling in biological networks varies considerably from scaling of common dimensions predicted by conventional Euclidean relationships (table 4.2). Because it affects so many biological phenomena across vast ranges of body sizes and levels of biological organization, West et al. (1997:126) refer to quarter–power fractal scaling as “the single most pervasive theme underlying all biological diversity.”
### Table 4.2

<table>
<thead>
<tr>
<th>Variable</th>
<th>Euclidean Relationship</th>
<th>Fractal Relationship</th>
</tr>
</thead>
<tbody>
<tr>
<td>length</td>
<td>( L \sim A^{1/2} \sim V^{1/3} \sim M^{1/3} )</td>
<td>( L \sim A^{1/3} \sim V^{1/4} \sim M^{1/4} )</td>
</tr>
<tr>
<td>area</td>
<td>( A \sim L^2 \sim V^{2/3} \sim M^{2/3} )</td>
<td>( A \sim L^3 \sim V^{3/4} \sim M^{3/4} )</td>
</tr>
<tr>
<td>volume</td>
<td>( V \sim L^3 \sim M )</td>
<td>( V \sim L^4 \sim M )</td>
</tr>
</tbody>
</table>

Common relationships between length (L), area (A), volume (V), and mass (M) as predicted by Euclidean geometry and fractal relationships found in biological networks. Adapted from table 2 in West et al. (1999).

Some isometric relationships in biology may even result from allometric relationships. Body mass, for instance, scales hyperallometrically (k > 1) with eye mass, and eye mass scales hypoallometrically (k < 1) with visual acuity. The relationship between visual acuity and body mass, however, is not allometric but isometric (k = 1). The relationship between visual acuity and body size may be accounted for by countervailing scaling factors (Kiltie 2000), meaning that even isometric relationships can theoretically be founded on more fundamental allometric relationships. In another example, world record running times scale as distance to the 1.14 power. Energy use in maximally exerted human males scales as time to the 0.858 power (Katz and Katz 1999; but see Savaglio and Carbone 2000). Combining the two equations, we find that the scaling of energy to distance is virtually isometric (k = 0.978).

In addition to metabolic networks, allometric scaling relationships also obtain for “extra–metabolic” networks. Combining equations for metabolic rates and biological rates predicts that biological rates scale as metabolic rates to the – 1/3 power (Moses and Brown 2003). Measures of body length have been shown to scale as \( M^{1/4} \) (Moses and...
Brown 2003; Niklas and Enquist 2001). When per capita power consumption is modeled as an extra–metabolic rate (W) and human fertility rate (R) as a related biological rate, R scales as $W^{-1/3}$. The same scaling factor is empirically obtained for the relationship between whole organism metabolic rate and annual fertility rate in mammals. Despite the evolutionary uniqueness of human techno–ecological systems and diverse tool kits for extracting and consuming available energy, fundamental allometric scaling relationships apply equally to biological and human systems of energy consumption and reproduction (Moses and Brown 2003).

Although the ubiquity of quarter power and three quarter power scaling in many biological phenomena has historically evaded explanation, recent work suggests that networks are responsible for these emergent properties. Fractal geometry and network growth processes successfully predict structural and functional properties of biological circulation systems (West et al. 1997, 1999). The common mechanism behind these scaling laws may be network topology: “Living things are sustained by the transport of materials through linear networks that branch to supply all parts of the organism” (West et al. 1997).

The evidence implicating network distribution systems is sufficient to allow Moses and Brown (2003) to “hypothesize that the scaling properties of extra–metabolic networks are similar to biological networks.” They convert the scaling of the delivery rate with network size to linear dimensions in order to model “the distance (l) and time (t) it takes for resource to travel from uptake to consumption,” finding that $l$ and $t$ scale as $V^{3/4}$ and as $E^{1/3}$ where $E$ is total energetic rate and $V$ is volume (Moses and Brown 2003).
They argue that “[t]hese scaling relationships can be generalized to describe the constraints on the efficiency of any three dimensional network” (Moses and Brown 2003). Because of these relationships, “as E increases, each unit of energy must pass through greater network length, l, incurring increased infrastructure costs” (Moses and Brown 2003). Thus, linear dimensions of networks are constrained by the cost of transporting energy through the network. As landscapes may be structured according to network topology, \( \frac{1}{4} \) power scaling may also obtain for landscape metrics. It may be the case, however, that a different set of scaling relationships may apply to systemic landscape variables, which may be more usefully quantified along two, rather than three, dimensions (area as opposed to mass).

Evidence for “landscape allometry” is building (Wu 2004). For instance, in one study of river networks, Hood (2002) found that components of hydraulic geometry – the shape and size of components of hydraulic system – scale with benthic ecology, leading to a series of interconnected allometric scaling relationships between ecological and hydrological dimensions of river networks. Surface flow velocities scale allometrically with channel form, resulting in “scaling of the exit time and export probability of floating detritus [which leads to] scaling of detrital sedimentation rates and thus to scaling of sediment organic content, spruce needle density in the sediments, and benthic surface deposit feeder density” (Hood 2002:1425-1426). Allometric scaling relations can thus be used in landscape ecology to predict where higher quality foraging areas (for surface deposit feeding fish) will occur along drainage networks. More fundamentally, allometric scaling in river networks may follow principles that apply to many types of
distributed, transportation networks “including the flow of water, blood, sewage, food, air and electrical currents” (Banavar et al. 1999:132).

The amazing ubiquity of power laws in biological and ecological systems suggests that power law relationships must occur in archaeologically studied behavioral systems. One problem with identifying power laws in archaeological data is that there is a lot of variability in the units and measures of archaeological dimensions. Only for the most basic dimensions (i.e., numbers of items or artifacts) do we have fairly consistent units and measures. Even so, for many fragmented artifacts we have no reliable methods for estimating minimum numbers of individuals or specimens (Hiscock 2002) and hence have little hope of understanding the relationships between archaeological frequencies of artifacts and systemic frequencies of items incorporated into behavioral systems. As such, another problem archaeologists face is that we have precious little understanding of how archaeological observations on archaeological patterns relate to systemic processes.

*Allometric Relationships and the Ethnographic Record*

Archaeological data are often highly skewed and their exact distribution is often difficult to characterize. Focus on relationships such as power law scaling could shift attention from analyses of variables in terms of average statistics (based on normal distributions) to analyses of relationships between variables. To do so, archaeologists need to consistently define and measure relevant variables along continuous dimensions.

High variability in ethnographic methods and reporting surely leads to a lot of noise in ethnographic data. However, cross-cultural ethnographic data are useful
heuristically to get a sense of the possible relationships between different systemic variables. Ethnographic data have been used to explore how properties of human organizational systems relate to properties of environments and properties of human–environment interactions (Binford 2001; Kelly 1995).

Given the prevalence of allometric relationships in biological systems of organization, we might ask if allometric relationships occur for ethnographically monitored variables. Are variables potentially related to the structure and function of ethnographically observed systemic landscapes allometrically related? If human interactions with systemic landscapes are organized according to network topologies, we might expect that measures of network path lengths, such as residential mobility, are allometrically related to measures of population size or population density.

Situating human groups against ecological frames of reference enables evaluation of how human systems compare to other “natural” systems studied ecologically (Binford 2001). For some variables, it may be the case that measurements on human systems fall comfortably within relationships comparing properties of many different species. However, it may more often be the case that humans can be situated within a broader range of values, corresponding to a wide array of species. In the case of human foragers and population density, human groups fall within the trophic level of carnivores, but also overlap with herbivores of similar body mass (Waguespack 2003). Other factors intervene to allow human foragers to exist along a range of population densities common to predators of both very large and very small body mass and some of the larger herbivores. Variability in human behavior may enable humans to occupy different
Figure 4.4 The allometric scaling relationship between population density \( (P_H) \) and average move distance \( (L_R) \) for human foraging groups \( (L_R = 21.727 * P_H^{-0.272}; r^2 = 0.510) \). Average residential move distance (km) from Kelly (1995, Table 4.1). Population density (persons / 100 km\(^2\)) from Binford (2001).

positions along allometric relationships that for other species are more strictly size dependent.

Due to size–dependent scaling of energetic requirements of organisms (the energetic equivalence rule), population densities of carnivores and herbivores relate hypoallometrically to body mass (Bini et al. 2001; Brown and Maurer 1986; Damuth 1993; Lawton 1989). Waguespack (2003) shows that the range of human forager population densities falls within the standard error of the relationship obtained for carnivores. The convergence of properties of human foraging space with properties of
Allometric relationships between measures of residential mobility and population density suggest that human foraging landscapes may function like extra–metabolic networks. The average residential move distance ($L_R$) scales as population density ($P_H$) to $\sim 1/4$ power (figure 4.4, data from Kelly 1995). Total, annual residential move distance ($L_T$) scales as $P_H^{1/2}$ (figure 4.5, data from Binford 2001). The relationship obtained for $L_T$ is consistent with expectations for Euclidean relationships between linear and areal variables and might have something to do with how Binford (2001) estimated

**Figure 4.5** The allometric scaling relationship between population density ($P_H$) and annual move distance ($L_T$) for human foraging groups ($L_T = 365.595 \times P_H^{-0.492}$; $r^2 = 0.650$). Annual residential move distance (km) from Binford (2001, Table 5.01). Population density (persons / 100 km$^2$) from Binford (2001).
Figure 4.6 The allometric scaling relationship between body mass (MC) and population density (PC) for terrestrial carnivores (PC = 277.971 * MC – 0.862 ; r² = 0.561). Data obtained from Waguespack (2003, Appendix A).

The range of \( L_T \) expands with \( P_H \), suggesting that higher population densities may be associated with greater variability in how resources are distributed throughout landscape networks. Alternatively, it could be the case that the power law exponent varies with characteristics of the environment.

The relationship obtained for \( L_R \) from data compiled by Kelly (1995) yields an exponent more consistent with expectations for fractal relationships. If we combine the allometric relationship for carnivore population density (\( P_C \)) and body mass (\( M \)) with the relationship for \( L_R \) and \( P_H \), we obtain the scaling relation \( L \sim M^{1/4} \). Oddly, this is the same scaling relationship obtained for measures of length (cell length, body length), suggesting that variation in human residential mobility is a property of systemic...
landscape networks that circulate energy according to organizational principles similar to those for other biological network systems such as metabolic networks.

Clearly, the above relationships are rather dispersed. The variance in these relationships suggests that dimensions other than population density play a role in determining residential mobility. It may be the case that different network topologies result from variation in both environment and foraging and collecting strategies. In the case of the relationship between $P_H$ and $L_T$, separating out cases according to environmental type is instructive. I examine the relationship between $P_H$ and $L_T$ for the two basic environmental types with the larger number of ethnographic cases – Tropical Rain Forest (TRF) and Tropical Desert (TRD). The examined ethnographic groups separate nicely according to average move distance and move frequency. TRF groups that move short distances ($\leq 5.7$ km / move) frequently ($> 20$ moves / year) appear to exist along a different relationship than TRF and TRD groups that move longer distances ($> 5.7$ km / move) less often. These groups are the Ache (Paraguay), Agta (Philippines), Aweikoma (Brazil), Hill Pandaram (India), Penan (Indonesia), Semang (Malaysia), and Shiriana (Venezuela). The Wintu of California and the Wind River Shoshone of Wyoming may also fall along this relationship, but unlike the other groups move longer distances (20 – 23 km) infrequently (6 – 14 moves / year). Three TRF groups in the sample move short distances but less frequently and do not fall along this relationship. These groups rely a fair amount on either aquatic resources or exchanged agricultural products and live at relatively high population densities ($> 40$ persons / 100 km$^2$) – the Ainu (Japan), Onge (Andaman Island), and Mbuti (Zaire). Three TRD groups also move...
residences short distances infrequently – the Anbarra (Northern Territory), Chenchu (India), and Yavapai (Arizona). The Yavapai are clearly an outlier for either relationship and relied to some degree on highly mobile raiding parties and practiced limited agriculture. Likewise, the Chenchu were attached to villages and practiced some agriculture while the Anabarra relied a fair degree on aquatic and state–provided resources. These kinds of power laws invite us to examine departures for interesting information.

If we consider only groups that moved short distances frequently and longer distances infrequently we obtain power law exponents of ~ 0.25 to ~ 0.5, respectively (Figure 4.7). Possibly, these exponents correspond to variation in residential mobility along Binford’s (1980) forager–collector spectrum. It is also possible that these relationships correspond to the fractal dimension of targeted resources. In the case of power law relationships having negative exponents (k), fractal dimension (D) is equal to \( \frac{1}{k} \) (Laxton and Cavanagh 1995). Foragers may move through landscapes along highly fractal pathways (D \( \approx \) 4), while collectors may move through landscapes along less fractal pathways (D \( \approx \) 2).
Figure 4.7 Relationships between LT and PH for TRF (triangles) and TRD (squares) groups. TRF groups that move short distances frequently (filled triangles) fall along the relationship $L_T = 406.4 P_H^{0.247}$ ($r^2 = 0.852$, $p = 0.001$). TRF and TRD groups that move longer distances infrequently (open squares) fall along the relationship $L_T = 338.8 P_H^{0.474}$ ($r^2 = 0.788$, $p < 0.001$).

Power Laws and Predictive Modeling

Power law distributions, which have the same general form as fractal relationships, have become of increasing interest because of the property of scale invariance. Such relationships suggest that, regardless of the absolute scale, relative changes in scale of one variable will result in a scale invariant change in a related variable. Power law relationships suggest no typical size or magnitude for investigated dimensions. Classic examples of scale invariance in the real world are earthquake
frequencies. As the number of observations increase, so does the population average as larger and larger, but less frequent, examples are encountered. The scale invariant property of power law relationships can, among other things, be used to calculate a scale–independent indicator, or the deviation of an observation from its expected value (Katz 2002).

As previously noted, power laws are observed in a wide variety of social, biological, and physical phenomena. Similar power law do not necessarily imply common causes, but the wide occurrence of power laws in natural systems suggests to some investigators that they result from highly generalized organizing principles that subordinate the relevance of many of the diverse details of any particular, investigated phenomena. As examples of self–organizing complexity, power law distributions tend to be found in three different kinds of general relationships: 1) frequency–size statistics; 2) networks; and 3) time series (Turcotte and Rundle 2002). All three kinds of relations have applicability to archaeological phenomena.

One of the reasons landscape ecologists pursue identification of allometric relationships is because power law distributions suggest self–similarity across scales (Song et al. 2005). Landscape ecologists have thus hypothesized that scale–invariant relationships observed in landscape samples can be used to “scale up” observed patterns to predict the properties of landscapes across broader spatial areas. To some archaeologists, “the inherent self–similarity of the fractal relation means that a regional sample can be extrapolated to a whole settlement system” (Brown et al. 2005:61)
As **systemic landscapes** may function as networks, some dimensions of **systemic landscapes** could be hypothesized as distributed according to power laws. Indeed, population distributions, wealth distributions, and distributions of recognition or prestige have all been shown to occur as power laws (Katz 2002; Merton 1968). Further, archaeologically observed dimensions (i.e., house area) that can be reasonably argued to directly relate to systemic variables (i.e., wealth) might also be hypothesized as distributed according to power laws (Bentley 2003b; Maschner and Bentley 2003). Brown et al. (2005) have recently argued that a wide variety of archaeological phenomena are appropriately described according to fractal dimension and power law statistics.
CHAPTER V — LANDSCAPES OF PERCEPTION, LANDSCAPES OF ACTION

Landscape and Space

Landscape is the spatial manifestation of the relations between humans and their environment...Landscapes are real world phenomena (Crumley and Marquardt 1990).

Landscape archaeology [is] the study of spatial relationships among humans and their physical, social, and cognitive environments (Savage 1990)

In a fundamental way names create landscapes. An unnamed place on a map is quite literally a blank space (Tilley 1994)

At a very general level, ethnographic descriptions suggest that people often treat landscapes as a collection of places connected by routes. Thus, a simple cognitive landscape may be composed of places and connections between them. Human interactions with landscapes may occur according to network topologies. These kinds of mental maps may be loosely defined as a collection of related things (i.e., things are related in space). The format or topology of mental maps may be composed of a variety of associations or relations between sets of places.

When used in the environmental sciences, the term landscape often connotes a heterogeneous, spatial array of one or more variables (Turner et al. 2001). When used to describe a cognitive or psychosocial phenomenon (e.g., imaginative or fictive
landscapes), landscapes may describe no real physical space. Phenomenologists argue that space is only relevant insofar as it is perceived and experienced. Metaphorical landscapes might have only spatial referents, tied to places in real space but spatially related according to some internal or cognitive geography (Tilley 1994).

Cognitive geographies, or the rules governing the conceptualized spatial and geometric relationships between landscape elements, may be idiosyncratic and contradict or defy classic Cartesian geographic relationships or topologies. Compared to professional, cartographic maps, “[m]ost cognitive maps are incomplete, are often distorted because of incomplete information, and require mental rotation, alignment, and matching as well as scale transformation when being used in travel planning or in actual wayfinding” (Golledge 2003). While the perceptual components of landscapes, as the interface between human interpretation and physical space, are important to understanding how or why people interact with landscapes, they create new, less tangible cognitive geographies. As socially constructed mnemonic devices, “[l]andscape features…form part of a grid of places that are well known to local people and form a complex non–Cartesian web of reference points on the landscape” (Basso 1996; Wilkinson 2003).

Golledge (2003) argues that environmental knowledge for many groups is obtained incidentally, rather than intentionally, and is thus more error prone than intentionally transmitted knowledge. Given imperfect knowledge of environments, that people successfully travel from one landmark to another is considered to be “boundedly rational” or “satisficing” (rather than optimizing) wayfinding behavior (Golledge 2003).
For many ethnographically studied groups, however, effective knowledge of landscapes is essential to survival. Successful hunting and trapping, for instance, requires exacting knowledge of physical terrain, spatio-temporal behaviors of prey species, and the effects of weather patterns on zones of potential economic activity (Brody 1981). A common landscape activity of the Nunamiut, for instance is the “walkabout,” or a “party engaged in teaching young men the characteristics of the environment” (Binford 1982).

Many ethnographically studied peoples are capable of expressing accurate cartographic information about very large areas (Kelly 2003). The intimate knowledge that Athapaskan hunters acquire of landscapes is exacting enough that first encounters with topographical maps seem familiar and second nature (Brody 1981). Effective knowledge of landscapes and their components, or classes, is so fundamental to Athapaskan hunting success that descriptive or predictive error of landscape processes or patterns is equated with dishonesty. To incorrectly describe a landscape feature or attribute is tantamount to lying (Brody 1981).

While cultural taxonomies guide the sensing and interpretation of lived environments, effective or successful interactions with landscape variables require that human agents have *practical knowledge of the performance characteristics and spatio-temporal configuration of important landscape variables*. Similar kinds of practical environmental knowledge have elsewhere been described as *locational knowledge* and *limitational knowledge* (Rockman 2003). Emic classification of landscape features, or *social knowledge*, may certainly differ from etic classifications, but this distance does not necessitate that emic classifications have no objective referents.
Naming Landscape Features: What Is In A Name?

Naming landscape features is a form of landscape cognition (Tilley 1994). The Kivallirmiut, inland Inuit hunters, organize their landscape according to the spatio–temporal properties of ecological resources. Of 272 documented place names used to organize the Kivallirmiut landscape, 76% can be described as eco–functional (124 literal / descriptive, 49 natural resources, 37 cultural / human activities). For the Kivallirmiut, landscape elements are thus most frequently described in terms of important ecological and behavioral properties (Stewart et al. 2004).

The remainder of Kivallirmiut place names are either related to historical events (n = 28, 10%) or metaphysical domains of knowledge and representation (31 metaphorical names, 6 spiritual, and 2 mythological names). Landscape cognition as conducted through the practice of naming places and landscape features is clearly biased in this case towards practical description of ecological and behavioral landscape properties. Sacrality and ritual play a role in this ordering of the landscape, but are represented less often in naming schemes. As the Harvaqtuurniut depend on caribou for their living, “elements of landscape often are described systematically in relation to caribou behavior, which is seen as being an unchanging landscape characteristic” (Stewart et al. 2004:192). Landscape properties that are essential to the performance of ecological activities, whether they be the spatio–temporal behavior of prey species or the relationship between topographical features and resource distributions, are fundamental to learning, representing, and teaching landscapes (Kelly 2003; Nelson 1986).
Figure 5.1 One dimensional and two dimensional representations of landscape structure. Place A is close to Place B and can be arrived at by following AB. Place B is close to C and can be arrived at by following BC. Place C is close to B along CB and a long way from D along CD. If all four places (A, B, C, D) were located on a two–dimensional, topologically correct map, one might easily locate a potential direct route between C and A. However, if the landscape is cognized in one–dimension, as a collection of related sets of places, then agents may believe that place A can only be reached from C by way of B.

Space Wanted: Place In Need of Space

Ingold (1993:154) argues that “landscape is not ‘space’.” Cartographers and surveyors may cut up, divide, and represent the world on a Cartesian plane, but to Ingold (1993) people know landscapes primarily as they intimately experience and remember them. In this view, places are not divisible from the landscape but inextricably embedded within larger zones of sensory experience and interaction. Although people may experience landscapes in personalized ways and personal experiences of landscapes will differ from how anthropologists or archaeologists choose to demarcate or define them,
logical empiricism requires a departure from the post–processual assertion of
insurmountable difference between the perceptually based organizing schemes of the
modern or postmodern world and those of everyone else. If some people – cartographers,
scientists, land speculators – cut up, divide, and define the world according to particular
ways of knowing and interacting with the world, then that (economic land classification
and alienation) is one way in which people cognize landscapes.

Investigations of land–use behavior suggest that people do not perceive the
landscape as continuous, unbroken swaths of land but as an array of places connected by
paths or causeways (Binford 1982; Chang 1992; Schlanger 1992; Stafford 1995; Stafford
and Hajic 1992; Zedeño 2000). Places may be conceived as stopping points or landscape
elements where any number of small–scale and medium–scale locational attributes
(topography, vegetation, visibility, shelter, proximity to water, etc.) aid in fulfilling
economic or social functions (Stafford and Hajic 1992; Stafford 1995). Indeed,
fundamental technological strategies support land use strategies requiring differential
provisioning of individuals, places, and activities (Kuhn 1995, 2004).

In addition to places and pathways, landscapes can also be conceptualized in
terms of surfaces, but such units are more difficult to conceptualize according to network
topologies. As components of cognized landscapes, places, pathways, and surfaces each
have zero, one, and two dimensions respectively. Ingold (1986) argues that foragers
establish landscape tenure in terms of places and pathways while food producers, who
clear, prepare, and plant fields, establish landscape tenure in terms of two–dimensional
surfaces. Specific knowledge of landscapes tends to reside in the characteristics of localities, rather than in general information about the environment (Kelly 2003).

The Siberian Khanty, northern foragers who hunt, fish, trap, and collect dispersed resources in riverside and forest settings, tend to organize landscapes in terms of hunting and trapping territories that vary (in size, shape, general characteristics, accessibility) according to their subsistence activities. The territorial compartmentalization of Siberian Khanty resource areas may be a way to improve foraging efficiency by ensuring that larger areas are searched (Jordan 2003). Interestingly, Jordan (2003) conceptualizes the constant movement of individuals along paths, through places, and across surfaces while tracking game as forming two-dimensional capillary networks along which tasks are performed. Over time, these landscape networks become sedimented in the repeated performance of specific tasks.

For inland Inuit, a major property of the archaeological landscape reflects systemic landscape cognition and performance. Inuit limit their activities (particularly with regard to processing or caching prey) on the north side of the river in order to avoid spooking caribou before they reach the river crossings. Archaeologically, only 14% of 1500 recorded features occur on the north side of the river despite similar survey coverage on both sides. Half the features on the north side of the river are Inuksuit – standing stones that “take the place of humans.” These stones were carefully placed to direct approaching caribou (Stewart et al. 2004).
Landscape Cognition

Many ethnographically known peoples have developed spiritual or metaphysical relationships with the landscapes they inhabit. While indigenous groups view themselves as occupying important positions within dense, interconnected social, ecological, and spiritual landscape networks laden with personal and cultural meaning, they also tend to organize landscapes into functional ecological elements or units (Johnson 2000). My purpose here is not to undermine the significance of sacred sites or ritual cartographies or to advocate a full return to ecofunctionalism. Rather, I argue that important components of emically cognized landscapes are emically-defined ecological resources. How resources are conceptualized emically should have important relationships to how people interact with landscapes in behaviorally meaningful ways (Johnson 2000; Okere 1979; Robbins 2003; Schlippe 1956). Archaeologists, of course, do not generally excavate prehistoric thoughts or explanations, but how people think about landscapes is partly a function of how people interact with ecological resources. It could be argued, for instance, that emic categories in some way reflect the kind, intensity, and frequency of interaction with resources.

Landscape Cognition and the Commodification of Land

Heilen and Reid (2005) argue that frontier homesteaders of the American West cognized landscapes in terms of economic, ecological, commercial, and political variables. In many cases, strategies for acquiring public land in the American West depended on the capacity of land to “do work” within a capitalist framework, in terms of
the exchange value of land as a commodity. Homesteaders cognized land according to natural and cultural properties perceived to affect the value of land as a commodity.

Sanford Ranch, a historic ranching homestead in southeastern Arizona, was likely selected from an array of available land parcels because of the convergence of valuable landscape properties: 1) close proximity to a proposed railroad route; 2) high quality livestock forage; 3) high access to water; 4) central location between existing and emerging commercial and military nodes. As a primary producer, Sanford Ranch was strategically placed to occupy an important position within an existing frontier landscape network. That the Sanford brothers cognized land in terms of its capacity to do capitalistic work is evidenced by their activities as merchants and suppliers who sold to local towns, mines, military outposts, and railroad workers. Land functioned as a commodity or a collection of commodifiable resources and thus was cognized in terms of attributes dictating the perceived value of land as a commodity.

Ironically, the treatment of land and its resources as commodities in the expanding frontiers of the American West forces one to recall Cosgrove’s (1984) association of landscape painting with the emergence of land alienation among elite members of capitalistic European society. Because of this association, landscape painting, and by implication archaeological landscape perspectives, is argued to externalize nature in a manner particular to capitalism. Despite shared historical backgrounds between the emergence of modern market economies and scientific naturalism, people still cognize land in terms of how they interact with it. How people cognize land is intimately associated with economic modes of production. Definition of
land and its resources as alienable commodities reflects only one of many perspectives on the relationships between people and environments.

People cognize land in terms of how they use it: in terms of how they get food and how they get the things that they believe they need. That some of the things they need are sacred, or that they tie themselves into sacred networks through landscape cosmology, should not be difficult to accommodate in this framework. The Sanford brothers, members of a migrating, expanding, usurping population, tied themselves into networks of places that ensured their livelihood. After the Sanford brothers were robbed of cattle en route to California, Don Alonzo Sanford traveled all the way across country to Washington, D. C. to register his grievance. Washington, D. C. was the place that held the power to do what he sought for himself and his family.

While frontier homesteaders might cognize land in terms of its capacity to do work as an exchangeable commodity or as a collection of commodifiable resources, non–capitalistic societies may cognize landscape elements in terms of their capacity to do work as dictated by alternative modes of production. That modes of production incorporate elements of the sacred does not negate the need to also incorporate profane, utilitarian, or functional elements in landscape classification. As Marx argued, what people do – or how people produce – is ultimately more informative than what people say (how people represent themselves and the world). The “conceptualization of nature…goes hand in hand with the process of its practical appropriation” (Valeri 1991:142)
Sanford Ranch, and other places like it, linked into a network of places through which material, energy, and information circulated. The local network included mining towns, military camps and forts, stores, transportation routes, and other ranching and farming homesteads. These were linked into larger population centers and transportation networks connecting the exploited regions of the American West. In turn, these were connected to larger political and economic networks that dictated the demand for Western products, the supply of external goods, and the rules and procedures for defining, measuring, and alienating land. Commercial enterprises like Sanford Ranch jockeyed for position as important nodes within hierarchically nested, capitalistic landscape networks.

When anthropologists investigate “cultural landscapes,” they are often investigating the ideological, cosmological, and mnemonic functions of places and landmarks within cognized landscape systems. When viewed in this way, landscape features are ritually significant, despite low–intensity material interactions and limited artifactual evidence of place use. While important, such perspectives on the relationship between people and landscapes are only one small component of much wider range of potential studies involving the interrelationships between landscape cognition and landscape behavior. Such perspectives demonstrate that – 1) people invest places with meaning; 2) that places with limited material traces of human activity may still be very important to particular groups; and 3) that people organize landscape elements according to cosmological principles that define their place in the world. Unfortunately, they delve little into the techno–economic functions of landscape elements. Since evidence for specific ideas and thoughts is generally lacking in the archaeological record, cultural
landscapes of this type do little to explain fundamental components of the archaeological record.

*Fractal Foraging Theory and Landscape Perception*

Optimal foraging theory has been applied in a variety of ways to archaeological issues, mainly in determining what the optimal decision matrix of human consumers should be given specific environmental resource constraints and return rates. Optimal foraging theory (Bettinger 1987; Kelly 2000; Smith 1983; Winterhalder and Smith 2000) basically asks the question: how is energy best spent to acquire resources? Ecologists argue that most foraging takes place in patches within spatially, geometrically complex environments or landscapes. Thus, the size, shape, and distribution of resource patches across landscapes exert influence on foraging strategies (O'Neill et al. 1988).

From an evolutionary perspective, how organisms perceive environments has fitness consequences. The inherent instability of humanized landscapes may favor strategic diversity and flexibility in foraging strategies. Fryxell (1997) examines the evolutionary stability of a range of basic habitat selection strategies (selective use of open habitats, selective use of dense habitats, opportunistic use of both habitats in proportion to availability, and facultative switching between habitats to maximize energy gain) within the context of Mendelian genetics and optimal foraging theory. Fryxell (1997) shows that although models of switching behavior are generally maladaptive (switching from one strategy to another) this is not the case for facultative habitat use (non–obligatory) when modeled in terms of search efficiency.
As long as one of two potential habitats is capable of supporting stable predator–prey populations, the presence of habitat switching behaviors can stabilize predator–prey dynamics. Fryxell (1997:697) hypothesizes that “the selective advantage of facultative choice would also be most intense in highly variable systems.” Moreover, “in unstable systems one might expect multiple behavioral strategies to persist among foragers” (Fryxell 1997:698). Organisms, of course, are not likely able to assess habitat quality perfectly. Fryxell’s (1997) habitat use model shows that sloppy foragers (that perform switching behaviors) have selective advantage over precise foragers, because the costs of investing energy in an incorrectly assessed, unproductive habitat are high relative to the potential fitness of being a precise switcher.

Another important variable influencing foraging behavior is the scale at which organisms perceive, or integrate information about, the landscape (Chust et al. 2004; Ritchie 1998). Certainly, human foragers will generally not perceive resource distributions at the same scale as harvester ants (Ribas et al.n.d.). An entire landscape composed of many harvester ant colonies and many resource patches could easily fit into a single resource patch perceived by humans. As resource distributions are fractal, exhibiting self–similarity over several orders of magnitude in observation, “resource density [is] scale dependent: different–sized organisms encounter different densities of resources in the same environment” (Haskell et al. 2002 527). In this sense, “a consumer with a large foraging scale may perceive a given fractal habitat as coarse–grained (i.e., containing a few large patches of resources), whereas one with a small foraging scale will perceive it as fine–grained (i.e. many small patches of resources, some of which are
contained in larger patches)” (Ritchie 1998:310). Behavioral decisions are formulated according to foraging scale and minimum patch size, two factors that basically translate in a spatial analytical context to extent and grain, respectively.

Assuming that many landscapes are fractal (approximately self–similar across a range of scales and decreasing in detail or length as scale increases), an organism operating according to larger scales of perception will ignore variation occurring at smaller scales. When the size or extent of the landscape (x) over which an organism integrates information is allowed to vary along with foraging scale (w), or the scale at which an organism perceives landscape features, patch encounter rates can be calculated as a function of patch size (s), per–unit–volume density of resource patches of particular size (s), extent (x), foraging scale (w), landscape fractal dimension (F), and resource fractal dimension (Q) (Eq. 3 in Ritchie 1998). Taking the derivative of encounter rate with respect to the decision variable of foraging scale (w) allows for estimation of the optimal foraging scale (z), such that z is approximately equal to a relationship between extent (x), resource fractal dimension (Q), and landscape fractal dimension (F).

In Ritchie’s (1998) fractal foraging model, the scale at which an organism perceives the landscape (what the units of perception or measurement are) can be predicted by the area (x) over which the organism integrates information (e.g., a territory) and the dimensionality of the landscape and its resources. Specialized use of resources is expected when foraging scales are large and generalized use of resources is expected when foraging scales are small. One might expect, for instance, that Paleoindian foragers (if they specialized in hunting large mammals) would have large foraging scales (would
perceive the landscape in less detail) than generalist foragers of the tropical rainforest, who might perceive their environment according to small foraging scales (relatively high level of detail).

One of the major predictions of this model is that “optimal foraging scale is strongly influenced by the landscape extent used by a forager rather than an arbitrary spatial extent imposed by an observer” (Ritchie 1998:318). In other words, the level of environmental detail important to a particular foraging strategy depends on, among other things, the size of a foraging territory. Thus, if we analyze foraging behavior at only small extents, we are likely to miss a portion of a foraging system.

Major predictions of Ritchie’s fractal foraging model:

“1. Optimal foraging scale is strongly influenced by the landscape extent used by a forager rather than the arbitrary spatial extent imposed by an observer” (Ritchie 1998:318).

“2. Landscape dimensionality and resource dispersion have opposite effects on foraging scale and patch use” (Ritchie 1998:319).

“3. Fragmented landscapes with lower landscape fractal dimension and higher resource fractal dimension (dispersion of resources) favour generalists that use a large proportion of available patches” (Ritchie 1998:319).
“4. High dimensional landscapes with resources distributed in large patches (low resource dimension) favour specialists that use a small fraction (potentially < 1 %) of available patches” (Ritchie 1998:319).

As Ritchie’s (1998) fractal foraging model is based on both classical optimal foraging theory and fractal theory, basic assumptions of the two theoretical frameworks carry over into the model. Namely, the fractal foraging model assumes “complete patch consumption, resource patches differ only in size, no depletion of resources” and that landscapes are fractal (Ritchie 1998:325). The model does not assume random patch distribution because fractal dimension captures much potential variation in patch distribution. A general prediction of the model is that highly dimensional landscapes (landscapes with high fractal dimensions) should promote predator aggregation and exploitation of a small proportion of available patches, while low dimensional landscapes should promote predator dispersal and exploitation of most available patches.

Having followed all this, we might question what factors determine the dimensionality of landscapes. Is fractal dimension an innate, immutable property of landscapes and resources or is it determined by the classification of landscape elements? In other words, might some landscapes have high fractal dimensions for some spatial variables and low fractal dimensions for others? The response of foragers to the dimensionality of landscapes might thus concern which variables are of interest to foragers.
The reason I follow this line of questioning is simple. A very general expectation for human settlement and land use is that human spatial behaviors will tend towards aggregation under some circumstances and dispersion under others. Increases in organizational complexity might result in the coagulation or aggregation of administrative offices within hierarchically arranged settlements. Increased agricultural dependence might tighten the geographic focus of agricultural groups resulting in increasingly aggregated agricultural settlement (or the opposite effect might occur such as dispersion of farmsteads by Kofyar agriculturalists, intensive, smallholder, frontier farmers of Nigeria (Stone 1993, 1996)). Highly mobile hunting groups, in contrast, who rely on highly mobile or spatially dispersed prey species might tend towards dispersion (at least while hunting).

If one has an area, such as the desert Southwest, where earlier people are not inferred to have practiced agriculture and later people are thought to have become increasing reliant on agriculture, it might be speculated that earlier populations were more highly dispersed and later populations were more aggregated. The truth may be far more complex, and depend on the scale at which aggregation is represented. Generally, dispersed foraging populations might aggregate at certain times of the year; aggregated agricultural populations might disperse to exploit spatially dispersed agricultural fields. Nonetheless, the potential for aggregation is probably greater with agricultural peoples than foraging people without agriculture.

All other things being equal, archaeologists view (in general) foraging communities as tending towards dispersion and agricultural communities as tending
towards aggregation. Foraging and agricultural strategies take place along a broad spectrum of social and technological interactions with landscape elements. Depending on the spatial structure of resources, the disposition of subsistence labor, the availability of land, seasonality and a variety of other cultural and environmental factors, both farmers and foragers have the capacity to be dispersed, nucleated, highly mobile, or highly sedentary (Graham 1994; Kelly 1995; Stone 1993, 1996). Unless we want to take an entirely environmental deterministic stance and demand that resource exploitation strategies depend entirely upon environmental stimuli, we must assume that the environment is a necessary but not sufficient condition for explaining foraging or agricultural subsistence strategies.

Theoretically, pure agricultural strategies and pure foraging strategies can successfully occupy the same physical landscapes. Accumulated long–term consequences of strategic interactions with landscapes, however, may influence the structure and availability of resources, resulting in resource structure and availability that is contingent on previous interactions. In the desert basin–and–range province of the Southwest, it is generally concluded that non–agricultural foraging strategies were exclusively implemented for much of the Holocene until a mixture of foraging and agricultural strategies began to occur during the late Archaic. While reliance on agriculture (agricultural kcal / total kcal) may certainly have varied during the late Holocene, it is generally expected that agricultural reliance increased during the late Holocene.
Some variation in agricultural reliance must certainly be accounted for by variation in the environment (specifically climate). In excessively dry years, much agriculture may not have been possible. This is perhaps a reason for the canal systems of the Phoenix basin, Arizona, in that they assured greater agricultural availability of water from extra-local sources despite high construction and maintenance costs.

Some variation in agricultural reliance must relate to other factors, such as established lifeways or existing ecological knowledge. When environmental factors are held constant, the tendency to perform agriculture versus non-agricultural foraging is based on perceptions of the environment and its capacity to “do work.” Food-producing landscapes might be more “continuous, high dimensional landscapes” (Ritchie 1998) in which only a small proportion of available patches are exploited. Foraging landscapes may tend toward “lower-dimensional, fragmented landscapes” in which most available patches are exploited. If the total environmental landscape independent of human behavior (in a given area) is the same for both potential food-producing and potential non-agricultural foraging strategies, then the dimensionality of the landscape and its resources depends on how the landscape is cognized.

Thus, how human groups perceive environments stems from technological strategies for exploiting environments. How human groups ultimately interact with environments, forming landscapes, relates to how they emically perceive existing, etic landscape elements. As humans progressively interact with environments, they also transform them, changing their dimensionality in more or less pronounced ways. As such, human technological strategies for exploiting environments must keep pace with
anthropogenically induced environmental change (e.g., switch to lower–ranked resources, intensification), incorporate environmental change as a component of spatially explicit and heterogeneous environmental interactions (e.g., agricultural fallow systems, resource “conservation”), or move to new environments (e.g., extensification / expansion, migration). I refer to these strategies as reflexive strategies, modular strategies, and mobilization strategies, respectively. Reflexive strategies are implemented as a reflex or reaction to environmental stimuli or conditions. For instance, foragers may switch to lower-ranked resources in response to rarification of higher-ranked resources. Modular strategies treat landscape elements as having modes dependent on resource availability and quality. Mobilization strategies require that people move into new areas in order to obtain resources. Each of these kinds of strategies can be applied singularly or in combination and vary according to social, spatial, and temporal scales.

First Encounters

When the first known human populations colonized the Americas, they encountered landscapes that were likely largely unaltered by previous human interactions. The environments they encountered were thus, in a sense, fully natural. They were not the sedimented, cultural palimpsests of past human–environment interactions. However, colonizing populations did not arrive as blank slates, without founding sets or packages of techno–ecological recipes for action.

Early Paleoindians, for instance, likely viewed environments similarly to their northeast Asian progenitors. North American environments may have not been exactly
the same as northeast Asian environments, but they had sets of recognizable fauna and foraging environments that existing foraging strategies could be mapped onto. Colonizing populations thus likely imposed their culturally inherited perspectives on how to make out on (now plentiful) resources.

Lacking prior experience with organized human hunting parties, the game that early Paleoindians are known to have hunted may have lacked defensive mechanisms of more harried prey. One enduring perspective on late Pleistocene biogeography argues that rampant over-hunting of Pleistocene megafauna caused sweeping, rapid extinction of numerous megafaunal species (Alroy 2001; Diniz-Filho 2004; Martin 1967, 1973; Martin and Wright 1967). The similarity in the timing of human colonization and megafaunal extinctions is well demonstrated for other areas of the globe (e.g., Australia, New Zealand), strengthening the case that human predation is intimately linked with extinction (Anderson 1989; Brook and Bowman 2004; cf. Grayson and Meltzer 2002; 2003; Surovell et al. 2005; cf. Wroe et al. 2004).

Human encounters with unaltered, “natural” environments may be high impact as a general rule. Around the globe, human hunting has been repeatedly shown to have had long term biogeographic consequences, having the potential to reduce both the overall size and abundance of highly ranked prey (Grayson 2001; Stiner et al. 2000; Stiner et al. 1999). The initiation of human interaction, even at very low densities, with natural landscapes is thus as a disturbance regime with broad-scale ecological consequences. However, the conflation of proximate causes, such as the arrival of human populations, with ultimate causes (e.g., excessive predation, ecological network disintegration, climate
change) could overlook some aspects of landscape structure and thus miss the essential message behind the interaction (Brook and Bowman 2004).

As studies of ecological networks have come to show, species interactions in ecological systems function according to network topologies. The foraging and reproductive behaviors of one species are linked to the foraging and reproductive behaviors of one or more other species, creating very large and complex networks that ecologists are only beginning to understand. Although it may seem logical that reducing or eliminating the population of one predator species or introducing another will have direct, proportional impacts on prey populations, this is not the case. Instead, introducing or eliminating species tends to have unpredictable impacts on ecolosystems. The elimination of some species may have little to no discernible impact, while the elimination of another might lead to a system’s total collapse (Yodzis 2000).

To address this problem, ecologists have developed the concept of keystone species, or species that function as crucial elements in ecological systems. From the perspective of network systems, keystone species function as highly connected nodes in small–world, hierarchical networks. These networks allow all species to be closely connected in ecological networks through series of complex (sometimes unanticipated) relationships. The random elimination of some species from a network could have very little impact on the total network, allowing most of an ecological system to remain largely intact, despite perturbation. The elimination of a highly connected keystone species could in contrast lead to the total collapse of an ecological system (Montoya and Solé 2000; Solé and Montoya 2000).
The massive, rapid extinction of numerous megafaunal species at the end of the Pleistocene gives the impression of a total ecological collapse. While early Paleoindians certainly preyed upon (or at least scavenged) some of these species (Waguespack and Surovell 2003), it seems to me unlikely that humans simply “over–killed” them all. Even under highly profligate hunting strategies that made only minimal use of quarried animals, it may be excessive to conclude that humans simply culled a vast, prodigious wonderland of Pleistocene megafauna out of existence (Brook and Bowman 2004; Grayson and Meltzer 2002, 2003; Wroe et al. 2004).

Today, no landscape is entirely humanized or entirely naturalized. While it is likely true that no landscapes of the modern era are without human impact, and prehistoric landscapes may well have seen more human impact than conventionally thought, nonhuman ecological and geophysical elements also make more–or–less continuous contributions to landscape formations. The ever–increasing ecological footprint of humans upon global environments is unprecedented in scope, but on vast evolutionary time scales human impacts perhaps represent something similar to other previous evolutionary eras such as the radiation of multicellular organisms or the age of the dinosaurs. The point is that, as landscapes become increasingly humanized, they see greater human impacts and modification, and they become partly organized according to human perception and design. Yet, agents of landscape formation are not exclusively human. Humanized landscapes are still subject to ecological flows of energy and materials and form landscape network systems that depend upon both human and non–
human inputs. Humanized landscapes may be further from equilibrium than theoretically
natural landscapes, and thus more susceptible to dramatic change or total collapse.
CHAPTER VI — LANDSCAPES AS NETWORKS

In a previous chapter, I noted that systemic landscapes can be conceptualized as composed of places connected by routes or corridors. Systemic landscapes may function as evolving networks of people, places, and connections between them. Recent advances in graph theory and mathematical studies of complexity have uncovered some astounding properties of many types of networks (social networks, neural networks, animal behavioral interactions, electric power grids). These properties allow similar kinds of networks to operate in many different kinds of contexts and across many levels of biological and social organization, from molecular systems, to living organisms, to ecosystems, to giant artificial networks of human construction.

In mathematical graph theory, the simplest kind of network is defined as “a set of items, which we will call vertices…with connections between them, called edges” (Newman 2003). In physics, vertices are called sites and edges are bonds. In computer science, vertices are nodes and edges are links. In sociology, vertices are actors and edges are ties. In behavioral archaeological terms, vertices are activities and edges are linkage factors, but can also be interactors and interactions respectively. In agent–based simulation modeling, vertices are agents and edges are interactions. For landscapes, vertices are places and edges are facilities that enable the exchange of matter, energy, and information between places.

Networks are often more than simple sets of connected items. Networks may have multiple types of vertices or edges. Vertices or edges may have associated
properties. Edges can be weighted according to the strength of connections between vertices or quantified in terms of distance or time. Edges can also connect vertices in one (directional) or both (undirectional) directions.

In mathematical graph theory, networks are often described as graphs. Directed graphs are networks in which every edge is directed in only one direction. Undirected graphs are networks in which edges are directed in both directions. An undirected graph can be represented as a directed graph by making each edge two directional edges.

An important property of networks is the number of connections between items. The term *degree* is used to describe the number of edges connected to a vertex. Directed graphs have an *in–degree* and an *out–degree* for each vertex. The set of vertices that can be reached from a vertex through a series of vertices and edges is called a *component*. Directed graphs have both *in–components* and *out–components*.

Length in networks is usually measured in number of edges. The shortest path (least number of edges) between vertices in a network is the *geodesic path*. Many real world networks have an average geodesic path between ~ 4.2 and 8.5, regardless of context. Effectively, this means that on average any vertex is separated from any other vertex by just a few edges.

One measure of the size of a network is *diameter*. Diameter is measured as the longest path between two vertices. Two other measures of network size are the total number of vertices (n) and the total number of edges (m). Interestingly, m scales to n in a linear fashion across a very large range of sizes for many different network types (Figure 6.1).
Newman (2003) identifies four general classes of networks that have been studied: social networks, information networks, technological networks, and biological networks. A social network is defined as a “set of people or groups of people with some pattern of contacts or interactions between them” (Newman 2003:174). Information networks are networks in which packets of information are connected in some fashion to other packets of information. Citation networks are classic examples of information (or knowledge) networks where papers (or patents) are vertices and citations are edges (Börner et al. 2004). Since papers can only cite earlier papers, citation networks are directional and acyclic (meaning they have no closed loops). Other examples of information networks are the world wide web (where web pages are vertices and hyperlinks between pages are edges) and networks of word relations in a thesaurus (Newman 2003).

Newman (2003:178) defines technological networks as “man–made networks designed typically for distribution of some commodity or resources, such as electricity or information.” Examples of technological networks are the United States power grid, road, railway, and airline route networks, physical connections between computers on the Internet, and telephone networks. Naturally occurring distribution networks, such as river networks, are sometimes considered analogous to technological networks.

Biological networks are networks of relationships between components of biological systems. Biological networks with similar scaling properties occur in all levels of biological organization, from interactions between molecules to extra–metabolic

Interestingly, social and information networks tend to be very large (have large numbers of vertices and edges), while studied biological and technological networks are considerably smaller (have fewer numbers of edges and vertices). My analysis of data compiled by Newman (2003, table 3.1) shows that despite large variation in network size, in terms of numbers of vertices and edges, all four types of networks appear to grow at a linear rate (Figure 6.1). On average, ~ 2 1/3 edges are added for each new vertex, regardless of the exact structure, details, or size of the network.

An important property of networks is their degree distribution. A degree distribution is the cumulative probability distribution of the number of edges per vertex. The degree distribution of many networks (but not all) has a power law tail, meaning that most vertices have a few edges, but small numbers of vertices have very large numbers of edges (Newman 2000, 2003). These are called “scale–free” networks because they tend to have similar degree distributions regardless of size. Adding additional vertices to scale–free networks has only minimal effect on geodesic path lengths. The rich–get–richer effect (or preferential attachment) is argued to be the process that explains scale–free network growth. New vertices attach preferentially to highly connected vertices and thus highly connected vertices accrue additional edges at increasingly higher rates than less connected vertices (Barabasi and Albert 1999). An analogous process in archaeology is the Arlo Guthrie trash–magnet effect, or “the tendency for trash to attract more trash” (Schiffer 1987:62; Wilk and Schiffer 1979).
Figure 6.1 The relationship between total number of vertices (n) and total number of edges (m) for social (open squares), biological (open triangles), information (filled squares), and technological networks (filled triangles). The relationship is virtually isometric: $m = 2.33 \, n^{1.06}$ (data from table 3.1 in Newman 2003).

Networks with power law degree distributions occur in social, information, technological, and biological networks. Examples are networks of collaborations between scientists, the worldwide web, citation networks, the internet, power grids, and networks of protein interactions. Directional networks, such as communication networks, have both in and out degree distributions with power law exponents ranging from 1.5 to
2.7. Undirected networks, such as film actors, sexual contacts, the internet, metabolic networks, and protein interactions, tend to have degree distributions with power law exponents between 2 and 3 (2.1 – 2.7, 95% confidence interval).

Network resilience is related to network degree distributions. Random graphs, assembled from random connections between vertices, have relatively even degree distributions. Like small-world networks, random graphs have low geodesic paths but are not clustered. Scale-free networks are also typically small-world networks, but unlike random graphs they tend to be more clustered and hierarchically structured because of preferential attachment (Barabasi and Albert 1999). When random networks are subject to random perturbations or disturbance (i.e., vertices are randomly removed), they have a tendency to break up into smaller network components and thus are not highly resilient to random disturbance. Scale-free networks, in contrast, are highly resilient to random disturbance because most vertices are only weakly connected and small numbers of rare, highly connected links maintain the connectivity of the network.

Non-random or targeted disturbance (i.e. preferentially removing the most connected links) is highly destructive to scale-free networks but not very destructive to random networks. This is because destroying a few highly connected vertices in a scale-free network destroys basic connections between very large numbers of weakly connected vertices. In contrast, the lack of highly connected vertices in random networks means that removing a few of the most connected vertices has little effect on connections between other vertices. Randomly removing vertices has almost no effect on average
vertex–vertex lengths, but removing vertices in order of rank (where vertices are ranked according to degrees) directly increases average vertex–vertex distance.

A final property of networks worth mentioning is network mixing. Since many networks contain a variety of different types of vertices, networks vary in terms of how different types of vertices interact with each other. Networks in which vertices connect preferentially to similar vertices are *assortatively mixed networks*. Networks in which vertices connect preferentially to dissimilar vertices are *dissortatively mixed networks*.

Identifying the mixing properties of networks can enable the delineation of community structure. In one study, a friendship network of United States school children is shown to mix assortatively according to race (White, Black, Other). Although the network clearly separates into four separate communities based on some criteria in addition to race, each community is composed almost entirely of two racial categories — either children of black and “other” races or children of white and “other” races (Moody 2001; Newman 2003).

A special case of network mixing occurs when vertices mix according to degree (number of edges). Although no explanation has been proposed, Newman (2003) shows that most social networks are assortatively mixed according to degree (well–connected people tend to connect with other well–connected people), but technological, information, and biological networks are generally disassortatively mixed.

*It Really Is A Small World After All*
The recognition of small-world networks follows from what is now known colloquially as the “six degrees of separation”, or “six degrees of Kevin Bacon,” phenomenon. Two people who have never met, live in distant cities or countries, and even participate in highly dissimilar social and economic contexts are often separated by only 6 or fewer interpersonal connections. The empirical reality of the phenomenon was demonstrated in a social experiment conducted by Milgram in the 1960s. The experiment enlisted Nebraskans to transfer a letter to an unknown person in Massachusetts by passing it on to someone they thought might have a chance of helping the letter along its way. Remarkably, one quarter of the letters made it to the intended recipient and did so on average between only six pairs of hands (Milgram 1967; Travers and Milgram 1969).

This famous experiment only probed a social network for its small–world properties. The experiment empirically demonstrated the small–world character of social networks, but no model was offered to explain this property of social networks. Since social networks tend to be highly clustered, the extremely efficient connectivity of social networks is counterintuitive. Only recently have mathematical advances in graph theory been capable of explaining how nodes in many different types of networks can be at once clustered and so highly connected (Newman 2000; Watts and Strogatz 1998).

In order to model small–world networks, Watts and Strogatz (1998) asked the question, how can social networks, which should be highly clustered (i.e. two people sharing a common friend are more likely to know each other) also be highly connected? To answer this question, they imagined two different kinds of networks: *cavemen* and *solaris* networks. In *cavemen networks*, everybody lives in small caves and small groups
of people all know each other but people between caves do not. In solaris networks, every¬
body lives in isolation but is directly connected to any other person through a global
communication system. These two extremes are essentially ordered (cavemen) and
random (solaris) networks (Watts 1999).

The interaction rules for actors are very different in ordered and random
networks. In ordered networks, two people who have one or more mutual friends are
highly likely to meet. In random networks, the probability of any two people meeting is
very low regardless of how many mutual friends two people have. Watts and Strogatz
created a tunable parameter value (alpha, varying between 0 and infinity) describing the
degree to which people interact with close friends and family. When alpha is very low,
people interact only with their closest neighbors (cavemen networks). When alpha
approaches infinity, people are just as likely to interact with one person as anyone else
(solaris networks).

Intriguingly, as alpha increases from zero, the minimal path between any two
people increases rapidly until it reaches a critical point beyond which minimal path
lengths collapse rapidly. Below this critical point fragmented ordered networks are
starting to coalesce, but the path length between any two individuals climbs to very high
levels. Beyond the critical point, increasingly random links connect distant network
components and create a giant network component. Greater frequencies of random links
continue to form, or connect up this giant component, until the network develops the
small–world character empirically recognized in real world networks. In essence, small–
world networks are made possible by a mixture of ordered and random interactions (Watts 1999, 2002b).

An astounding property of small-world networks is not just that so few edges are required to connect any two vertices, but that agents are capable of efficiently navigating these complex networks. Apparently, it is the presence of order, or clustering, in networks that enables a small percentage of social actors from Nebraska to transmit a letter through a few people to a person in Massachusetts. The small-world effect occurs only when heterogeneous local connections transmit information about the larger network structures. The presence of fine-scale local heterogeneity allows network agents to interpret the relationship between individual nodes and the overall structure of the network (Kleinberg 2000).

When networks are entirely ordered, the number of connections required to get from one end of the network to another is very high. Traveling from one node to a distant node is highly inefficient, requiring the interaction of many interconnected network links. In random networks, distant nodes can be reached within very small numbers of links. In random networks, there are no strong alliances, no communities, no centers of activity, and no highly connected nodes. The opposite may be true for ordered networks which are organized but grossly inefficient.

Small-world networks combine the best of both extremes by allowing a combination of order and entropy to coexist. Random networks are highly connected but lacking any interpretable order and so cannot be efficiently navigated. The sprinkling of ordered networks with random links allows a remarkable property to emerge. Random
links connect otherwise widely separated clusters of more closely connected nodes and enable one node to be connected to any other node through a very small number of links. For small–world networks, the average number of connections remains extremely small across all orders of magnitude, regardless of whether the network is composed of one hundred or six billion nodes. Any area of the network can be reached quickly regardless of the absolute size of the network and the degree distribution of the network changes only minimally with changes in network size. Hence, some real world networks of many different types (social, biological, technological, information) share some fundamental properties. They are both small–world and scale–free.

*Places As Nodes*

Given emic and etic conceptualizations of landscapes it is relatively easy to see how areas conceptualized as places, regardless of exact function, could function as nodes within evolving physiographic, social, socio–mythological, political, economic, and ecological networks. Given the winnowing effects of site formation processes and the many problems archaeologists face with interpreting function, it is generally hazardous to make a lot of assumptions about site functions, despite the imperative to integrate particular kinds of sites within larger, inclusive, settlement systems. While the presence of particular recognized features can allow some behavioral functions to be inferred (i.e., water control, food preparation, habitation) and functional types to be assigned (i.e., reservoirs, roasting pits, house pits), the archaeological absence of particular feature types does not necessarily preclude the prehistoric, systemic occurrence of particular activities.
Moreover, exclusivity in interpretation of archaeological site functions is potentially hazardous and simplistic. It is more conservative to allow for multi-functionality. However, making all sites potentially multifunctional, excepting those where physiographic or environmental evidence can be marshaled to argue that some particular functions could not be carried out in a limiting environment, reduces our ability to interpret how sites may function within an integrated, functional network system.

Given criticisms of the site concept during the past two decades, it is imperative that archaeologists limit assumptions about what sites, both in general and particular, actually represent in terms of systemic behavior. In most implicit treatments of the site concept, sites take on a certain culture-historical and functional stability by virtue of their recognition despite the fact that a great many different kinds of processes could result in the archaeological recognition of a concentration of artifacts and/or features in a particular area as opposed to adjacent areas in a study area.

Much recordation and understanding of sites, as places, is intuitive and commonsensical. In some cases, there may be a reasonable correspondence between intuitive judgments of the presence of sites and the actual occurrence of spatially discrete place-based interactions. Precious little middle-range theory has been developed or invoked to explain why archaeological sites can be equated with systemic places. While it may be reasonable to posit that people conceptualize landscapes as collections of places that variously afford the performance of activities, an area recognized as a discrete archaeological site does not necessarily constitute a discrete place in systemic context. In truth, an archaeological locus that today appears as a single, discrete archaeological site
may represent in systemic contexts a collection of places, overlapping portions of partial places, and/or no place at all (Schiffer 1975).

For instance, along major river systems in the arid Southwest (e.g., the lower Santa Cruz River), archaeological survey generally recognizes sites from the surface manifestation of artifact concentrations and fairly limited, unobtrusive archaeological features (i.e., rock scatters interpretable as roasting pits, concentrations of apparent soil staining and possibly cultural charcoal). Given the highly transient nature of these fluvial and alluvial surface environments, it is entirely conceivable that surface archaeological manifestations represent a combination of reworked and transported artifact assemblages that are undergoing spatially heterogeneous processes of exposure, burial, and transport almost continuously over short time scales. Rather than representing material correlative concentrations of systemic behavior, such surface archaeological manifestations as well as corresponding, archaeologically sparse or barren areas may more closely reflect current and past earth surface processes than spatial variation in systemic behaviors.

Nonetheless, archaeological surface manifestations recorded as sites may be frequently subjected to further subsurface investigation. The recognition of subsurface features, such as roasting, storage, and residential house pits, artifact concentrations, and site furniture (e.g., metates), could be interpreted as empirical confirmation of the residential site status of previously observed, vertically overlapping surface artifact deposits. While it is at least conceivable that artifacts observed at the surface may be directly related to underlying subsurface deposits through the effects of disturbance processes or long–term continuous place usage, behavioral linkages between surface and
subsurface deposits may not exist. The common denominator between surface and subsurface deposits may in some cases be only that the material consequences of past activities occurred in the same area.

In deep, alluvial, riverine desert basin contexts, where Holocene sedimentary deposition can be tens of meters deep, the potential for buried cultural deposits should be relatively high. It may even be the case that almost any subsurface location within a specific geophysical zone has a more or less equal probability of retaining evidence of prehistoric residential activity. Worse still, the coarse temporal resolution of available chronometric methods (e.g., radiocarbon dating, archaeomagnetism) in desert basin contexts — at least in terms of relevant behavioral scales — means that cultural subsurface deposits at similar depths may be further apart in time than they appear.

A more reasonable assumption to make about the material relationships between activities and archaeological manifestations in desert basin contexts (and perhaps for a wide variety of other contexts) is that artifact deposition and feature generation are spatially contiguous over long time periods. In topographically, geologically, and hydrologically variable contexts, it would be unreasonable to assume that artifacts and features could occur everywhere with equal probabilities, but it may be reasonable to assume that different environmental zones are more likely to trap, display, or obscure artifacts. Further assumptions can be made about which environmental zones are likely to have contained important ecological resources at various times in the past. Thus, which areas are more likely to have been traversed, accessed, or perturbed by human interactions can be hypothetically reconstructed. Areas with a high probability of access
and land use (i.e., valley axes) could be assumed to have collected or trapped relatively continuous arrays of artifacts and features.

The fact that surveys and excavations often find apparent spatio–temporal variation in artifact and feature clustering, density, and functionality could be addressed from a different direction, or proceed from a different set of assumptions. The assumption that archaeological concentrations represent concentrations of behavior leads to the perception that variation within and between these concentrations should be the focus of our investigations. It may be more reasonable to assume that clustering of archaeological materials is likely to exist in particular kinds of environmental zones. We should instead question why gaps and variations in density exist between these more obvious concentrations. Does the absence of surface artifacts correspond to the absence of subsurface artifacts and features? Does the co–occurrence of both surface and subsurface cultural deposits correspond to stable, long–term place usage? Does the presence of low density or barren areas between concentrations relate to: 1) erasure, scouring, transport, burial, or decomposition of artifacts and features through environmental processes; 2) methodological or perceptual variation in the “sensing” or apprehension of archaeological evidence; or 3) spatial variation in contemporaneous, asynchronous, or modern systemic behaviors? These are rather large questions, and very difficult to answer. These are questions whose answers we can only approach through long–term, continuous research programs that do not assume one–to–one correspondence between spatial patterning in archaeological manifestations and spatial patterning in systemic behavior.
How archaeologists go about trying to answer these kinds of questions in specific contexts should depend on the development of reasonable sets of dependable assumptions designed for specific kinds of artifact performance characteristics and archaeological contexts. For instance, abundant survival of organic remains should occur as a result of: 1) conditions that limit exposure to decompositional processes (e.g., bogs, caves, freezing temperatures) or 2) temporal limitations (e.g., rapid uninterrupted burial, recent organic deposits have less time to decompose). The scarcity of organic archaeological remains in many sampled contexts is not generally interpreted as meaning that systemic behaviors favored the use and/or deposition of organic materials in the places where organic artifacts are found archaeologically. The presence of such remains is usually interpreted as resulting from the greater contextual likelihood of organic preservation.

Why should we reverse such an assumption when considering concentrations of more durable artifacts interpretable as sites? Why should we assume such concentrations correspond closely to spatial variation in artifact-generating and depositional behaviors? After some debate, archaeologists now studiously avoid assumptions such as “pots equal people.” Likewise, archaeological sites do not equal camps, villages, or specialized processing areas. While such kinds of systemic place use do result in the formation of archaeological deposits, interpreting individual archaeological sites as temporally and spatially discrete places requires more rigorously tested inferences.

If people randomly lose or discard artifacts while they move across landscapes, then (without subsequent disturbance) the distribution of artifacts should relate to patterns of movement. For instance, if people traveled along routes or corridors, searched or
foraged within patches or ecozones, camped or resided in locations of varying stability and duration, the distribution of artifacts should relate to how much time they spent where, so long as artifact deposition is probabilistic and occurs at a fairly constant rate. Of course, artifact loss or discard is likely related to a variety of contingencies which serve to further complicate the generation of archaeological landscapes. And, the loss or discard of artifacts probably scales to behavioral mobility at different rates. Different kinds of artifacts have different use–lives, different probabilities of being lost or discarded under varying behavioral and environmental conditions, leave material remains or fragmentary artifacts resulting from incidental material loss as a result of manufacture, use, or damage and breakage remnants of varying sizes and proportional frequencies.

To complicate matters further, different quantities and types of archaeological artifacts correspond to different functional systemic units. For instance, a single ceramic jar might break into 150 sherds while a metate might break into 10 fragments and a projectile point into only 3 fragments. Some broken fragments might be recycled or reclaimed, others left in place, and still others removed to secondary trash deposits. While some effort has been made to estimate minimum numbers of individuals (MNIs) for artifactual categories other than faunal remains, such efforts are in their infancy and are still far from being robustly applied across a variety of comparable artifactual categories (Hiscock 2002; Schiffer 1987).

Different artifact size fractions, material densities, surface topographies, and morphologies likely have variable rates or probabilities of vertical and horizontal transport. These generally unknown rates and probabilities of transport also likely vary
according to hydrological (i.e., fluvial vs oscillating), sedimentological (i.e., surface
texture, entrainment), eolian (i.e., steady directional winds, vortices, windspeed), and
sloped (i.e., slope, aspect) conditions. Attempting to account for all this potential
variation seems a monumental and perhaps almost impossible task. The complexity of
potential interactions between numerous variables seems to preclude the possibility of
making accurate predictions about spatial patterns in archaeological materials. Some
combinations of processes, however, are more likely to occur than others in specific
environments.

We could view these interacting variables as a highly complex, spatio–temporal
system. From a complex systems perspective, it is nearly impossible to predict the exact
details of such human–material systems. Minor variation in the initial conditions of such
systems tends to lead to unpredictable, large scale divergence between initially similar
systems (Rauch 2002). On the other hand, such systems might have certain predictable
emergent properties and tend to organize themselves in similar ways. Despite the fact
that individual landscape patterns could be as different from each other as one snowflake
or one fingerprint is from another, they may have other properties that are almost always
the same. They may be of similar size, have similar numbers of components, be
connected in similar ways, have predictable distributions of resource densities.
Snowflakes, by the way, have a variety of predicable properties despite the dogma that
each and every one is unique (Bentley and Humphreys 1961). Likewise, landscapes may
fall into a few general categories or exist along the gradients of a few fundamental
dimensions despite their apparent complexity.
Persistent Places as Major Hubs

Successful performance of activities involving anticipation of frequent or unscheduled movements about the landscape requires individuals to be provisioned with the tools and raw materials necessary to the performance of common tasks. In conditions where the use of specific places is both persistent (Schlanger 1992) and anticipated, technological strategies may favor provisioning places over provisioning people. Higher investment in provisioning places should occur when residential movement is relatively infrequent, occupation duration is relatively long, and the range of logistical mobility is comparatively wide. Keeping in mind the fact that most behavioral systems will employ combinations of logistically and residually mobile land–use behavior, the degree to which places are provisioned should reflect the kinds of land–use strategies in which different places are involved (Kuhn 1995).

Major, primate, central, or capital places continue to be loci of behavioral inputs over long time periods and may persist as major nodes in landscape networks corresponding to multiple overlapping behavioral systems (Lekson 2002; Rapoport 1993). Places that contain major community features, such as monumental or communal architecture (ballcourts, platform mounds, reservoirs), attract linkages to disproportionately large numbers of other places. Mesopotamian tells, for instance, retain highly visible archaeological signatures of spoke–and–wheel transportation routes that connected major community centers to outlying agricultural and pastoral zones as well as other tell sites (Wilkinson 1994). In the case of major sites with major constructed
features, we can generally be assured of the placeness (corresponding to a systemic place) of an archaeological site.

In most cases, however, a high level of uncertainty exists in establishing inferential relationships between archaeological sites and systemic places. Sites could represent remnants of overlapping systemic places as well as the cumulative material remnants of more spatially random processes (Banning 2002). The presence of constructed features affirms the “placeness” of a site, but not necessarily the temporality. Site features could represent the spatial clustering of similar but independent and asynchronous activities as much as they could represent planned use and reuse of a known or inhabited place. Large clusters of courtyard residences could represent a wide variety of temporalities. The scale and degree of synchrony or contemporaneity among residences and among courtyard clusters has to be determined in order to establish the temporality of place use.

The temporality of material correlates for systemic behavior can be described according to three components: 1) contemporaneity, 2) synchrony, and 3) continuity. These are roughly analogous to the concepts of duration, simultaneity, and succession (Holl 1993). Behaviors can be considered contemporaneous if they occur in the context of the same behavioral system or occur during the same general time period. Little effort has been made to establish or estimate the spatial and temporal parameters of behavioral systems, but it is possible that, like biological systems, they keep their own kind of time. Often, it may be impossible to tell archaeologically whether behaviors with material consequences occur at the exact same time or within days, weeks, months, years,
decades, or human generations of each other. Nonetheless, lacking any data to suggest the exact timing of an event or process, we may often consider a number of occurrences to be roughly contemporaneous, regardless of the exact sequence of events.

Another component of temporality is synchronicity. Activities can be considered synchronous if they occur simultaneously within the context of a behavioral system. Two different camps could be synchronous occupations by two different task groups or families, or asynchronous if one is occupied after another. Whether activities or processes are synchronous or asynchronous is process specific. For instance, the manufacture of flaked stone bifaces around two different camp fires could occur at different times over the course of a single day, days, or weeks. The archaeological consequences of biface manufacture around the two camp fires could be considered contemporaneous (occurring over roughly the same period of time) but potentially asynchronous (occurring at different times during a general time period). Though activities occurring around the two camp fires may occur asynchronously over short time scales, the use of the two camp fires as sources of heat, light, and smoke, and foci of activities could be synchronous. Whether activities are considered contemporaneous or synchronous has a lot to do with scalar issues, or the units with which time is measured.

A third component of temporality is continuity. Consider the possibility that the two hypothetical camp fires above are not simultaneously used. Instead, they are established and used during different annual visits to the same place. The camp fires are now used asynchronously, as is place use. Place use, in this case is spatially redundant but temporally discontinuous. This may seem an unnecessary complication of the timing
of activities observed in the archaeological record, but it is not. The fine-scale
temporality of material correlates for systemic behaviors is often extremely difficult or
even impossible to establish. Yet, archaeologists make a lot of generalizing assumptions
about the temporality of systemic behaviors, many of which ultimately feed into broad
interpretations of major systemic processes occurring over long time scales.

Take, for instance, residential occupations. If, as often occurs in the Tucson
basin, a large number of residential features are observed in a general locale,
investigators generally conclude that this concentration represents continuous occupation
of a single place by a large number of people over an extended (supra–annual or supra–
decadal) period of time. Indicators of time (i.e. diagnostic artifacts, radiometric dates)
may span long periods, such as hundreds of years, leading investigators to conclude the
presence of a large, highly persistent sedentary village occupied for centuries. While
deep sedentism cannot be entirely ruled out from such evidence, many different
temporalities could explain the same general pattern. It is imperative that these
alternative temporalities be rigorously explored before one firmly settles on the
conclusion that such archaeological patterns represent very long–term, fully sedentary
villages.

Interpretations of place–use necessarily inform interpretation and reconstruction
of landscape level behavioral processes. For instance, concentrations of apparently
clustered residential structures, storage structures, and activity spaces may often be
considered to be synchronously occupied and thus interpreted as a large village.
However, these clustered structures may only be contemporaneous in terms of coarsely
defined chronological periods of long duration and instead be components of discontinuous and / or asynchronous patterns of settlement and land use.

Routes As Links

An important component of landscape evolution is the development of pathway networks (Zedeño and Stoffle 2003). Complex, localized pathway networks develop as resource use becomes regularized and human traffic increases (Zedeño and Stoffle 2003). The trampling and smoothing of vegetation and surface contours allow regularly used pathways to become more visible and comfortable with time and thus to invite more usage (Helbing et al. 1997; Zedeño and Stoffle 2003). Heavily used pathways are often invested with facilities — “stones, cairns, petroglyphs, trail–marker trees, stepping stones…, rope and hand–and–foot rails, and wooden bridges” (Zedeño and Stoffle 2003:63) — that increase the durability, visibility, and coherence of prehistoric trail systems (Rogers 1939, 1966; Tani 1995; Zedeño and Stoffle 2003:63). Through continuous usage, such invested pathways can also be continuously maintained.

While we tend to think of pathways as ways to get from one place to another, the act of traveling along pathways can be an important kind of landscape interaction (Zedeño and Stoffle 2003). Likewise, pathways form important linkages between nodes or places within landscape activity networks. The timing and intensity of pathway disturbance as well as structural changes to landscape networks can of course lead to the disuse and erasure of established pathways. On the one hand the visibility and comfort of established and maintained pathways can lead to their further integration into patterns of
landscape connectivity (i.e., animal trail systems incorporated into indigenous trails systems, still later incorporated into planned transportation systems [i.e. roads, railways]).

Road systems of political centers attempting to establish connectivity with distant network nodes may be centrally planned and require heavy investments (e.g., Chaco and Inca Road systems), representing centrally organized attempts to establish the hierarchical significance of particular places within landscape networks. Pathway networks can also evolve through self–organization (from the bottom up) through the interaction of individual agents with components of evolving socio–ecological landscapes. It is these latter kinds of self–organized pathway networks that may accurately reflect landscape usage as it pertains to the flux of natural and cultural resources.

Helbing et al. (1997) have modeled the evolution of human trail systems and concluded that important variables for the evolution of self–organized trail systems are likely to be: 1) ground conditions (reflecting the comfort of walking); 2) weathering rate (related to the durability of trails); 3) trail distance; 4) trail visibility; 5) direction of destination. Simulated trail systems modeled according to these variables compare well with empirically observed, unplanned trail systems in urban environments (Helbing et al. 1997). This model, however, underplays the significance of the frequency of travel in determining the formation, maintenance, and development of trail systems. Ultimately, the evolution of self–organized trail systems depends on the use–intensity of particular destinations and the frequency of travel between nodes, in addition to the variables listed above. Theoretically, the relative use–intensity of particular places within landscape
networks (as well as temporal changes in use–intensity) could be inferred from the structure of pathway networks.

*Network Model of Human–Environment Interactions*

If anything, behavioral archaeology has emphasized the importance of identifying and investigating interactions between people and materials in all times and places (Reid 1995; Reid et al. 1974; Reid et al. 1975). Behavioral archaeology has also emphasized investigating the roles of both natural and cultural formation processes (at a variety of different scales) in forming and transforming the archaeological record (Schiffer 1987). The archaeological record is neither entirely random with respect to behavior, nor is it entirely organized by behavior. To put it another way, the archaeological record is not entirely the product of human design, intentionality, action, or adaptation. Nor is it the product of entirely supra–behavioral or non–behavioral processes. Instead, the archaeological record is the residual consequence of an enormous array of interacting natural and cultural processes occurring across a broad range of spatial and temporal scales. At times, exactly how different formation processes interact to form the archaeological record appears to encompass phenomena of almost overwhelming complexity. A similar situation in ecology provokes the comment that “[s]cientific disciplines without a good framework of rules and laws are generally considered the poor relations of their ilk, and, as human impacts on our planet appear to have reached alarming levels, the need for reliable ecological theory is hard to overstate” (Whittaker 1999 865).
The archaeological record is part of a totalizing system of interactions that are often difficult to disentangle. A general goal of archaeology has been to infer behavioral processes from archaeological patterns. In order to achieve this goal, formation processes must be identified and taken into account (Schiffer 1983; Schiffer 1987). In order to draw reliable inferences about systemic behavior, archaeologists need to establish a framework that conceptualizes the nature and organization of formation processes, assesses their influence on evidence of past behaviors, and empirically identifies relationships between formation processes and specific deposits (paraphrasing Schiffer 1983:676). A basic conceptualization of the archaeological record is that it is created ultimately by behavior, refracted or distorted by post–depositional (or post–behavioral) processes, and sampled according to both formational (see Cowgill’s model below) and methodological bias.

In identifying the role of formation process studies in archaeology, Schiffer (1983) outlines several models of the nature and organization of formation processes: 1) Ascher’s (1968) “entropy” model; 2) Cowgill’s (1970) “sampling bias” model; and 3) the “transformation” model of behavioral archaeology. In the first view, the effects of time degrade the quantity and quality of artifactual evidence, leading to loss of information or entropy over time. In the second, natural and cultural processes progressively sample behavioral systems and archaeological deposits, leading to increasingly biased samples of populations of interest to archaeologists. The physical finds population is a progressively biased sample of the physical consequences population. The transformationist view, perhaps the most empirically and theoretically grounded of the three, stresses that
“diverse processes transform or distort materials, and the many ways they do so: formally, spatially, quantitatively, and relationally” (Schiffer 1983:677). A fundamental contribution of the transformation approach is the recognition that “formation processes themselves exhibit patterning [and thus] can introduce patterning of their own” (Schiffer 1983:677-678). The promise of the transformation view, then, is that laws governing formation processes can be used to infer the effect of specific processes upon archaeological patterns. As a consequence of this reasoning, Schiffer (1983:678) stipulates that “as a prerequisite for making virtually all archaeological inferences, the archaeologist must identify the processes that give rise to the specific deposits that are to supply relevant evidence.”

The number and diversity of formation processes that have since been catalogued and explored is expansive. As has been stressed, the relevance of particular formation processes, and the detail with which they must be investigated, relates to the archaeological problem of interest. Many formation processes have been investigated in terms of artifact or site dynamics. That is, they pertain to the building of archaeological inferences in terms of particular sites or particular artifact assemblages from one or few sites. Expanding the field of inquiry, by changing the spatial or temporal scale of investigation, should markedly increase the number of relevant or contributing formation processes. If we are to extend the transformation view to investigation of archaeological landscapes, how can we proceed?

One way to proceed is, of course, to consider landscape–scale formation processes. Broad–scale regimes of sedimentation and erosion, biological activity, or
human–environment interactions must be addressed. In the same sense that there is an analytical hierarchy in units of analysis such as artifacts, sites, and landscapes, there are also hierarchically organized processes, operating at different scales and exerting different degrees of influence on archaeological patterns when viewed at different scales. In the case of the desert basin–and–range province, for instance, variability in topography and weathering properties fundamentally relate to spatial patterns in ecological distributions.

A productive approach to conceptualizing the archaeological record is as a multi–dimensional complex system. The dynamics of complex systems suggest that complex patterns can result in a non–additive fashion from the interaction of relatively simple strategies, rules, or processes. The global properties of complex systems are formed by the interaction of locally occurring interactions. Thus a complex system such as an archaeological landscape is not so much a simple aggregate of elementary, contributing processes, but a system of interactions that forms a more complexly ordered whole. The global properties of complex systems emerge from simple interactions.

Archaeological landscapes, as complex systems, are networks of interacting natural and cultural processes. The global properties of archaeological landscapes, then, are not the direct result of human organizational systems or strategies, nor are they entirely the product of natural processes. Archaeological landscapes may exist somewhere near the edge of chaos, at an interface between randomness and order. We cannot reliably interpret patterns of archaeological landscapes as the output of one or a few behavioral (i.e., mobility strategies, population size) or supra–behavioral (i.e.,
erosion, climate) inputs. **Archaeological landscapes** result from the interaction of many different processes.

In interpreting, or making sense of, **archaeological landscapes**, our task is to attempt to identify the potential relationships between global patterns and local processes. Two interrelated global properties are site size and artifact density. Artifact densities are not uniform across **archaeological landscapes**. Some areas have few to no observable artifacts while others are extremely dense. In some areas artifacts consistently occur at uniform densities while in other areas artifact densities vary wildly. It is often tempting to relate these variations in artifact densities to some combination of behavioral and non-behavioral processes. For instance, spatially organized behaviors (i.e., secondary refuse disposal, residential activity, localized resource extraction) may be hypothesized to occur in specific locales and thus result in distinct, higher density concentrations of behaviorally-related, artifacts. Spatially random behaviors (i.e. artifact loss; continuous broad-scale manuring) may be hypothesized to occur without respect to spatial variation in environments or spatially localized behaviors, resulting in lower density, more continuous artifact distributions.

On the other hand, natural processes (i.e., bioturbation, erosion, alluvial deposition, weathering) may be considered to exert influence on the concentration, visibility, or survivorship of artifacts. For instance, limited survey evidence for Paleoindian occupation of large areas such as the lower Santa Cruz River basin may result not from lack of Paleoindian occupation but from post-Paleoindian cycles of erosion that removed or buried deposits of appropriate age. Further, high rates of late
Holocene deposition may have differentially eroded and buried Archaic cultural deposits, resulting in a record biased towards discovery of later Hohokam deposits. While climate–driven variation in environmental conditions may have induced variation in human population levels and subsistence activities at various points in the Holocene (i.e. mid–Holocene altithermal), climate–induced variation in the sedimentary archive and thus the potential record of human activity must also be taken into account in order to reconstruct the past.

To some investigators, power law distributions are the signature of complex systems. As recurrent properties of many different kinds of physical, biological, and social system, power law relationships are increasingly considered indicative of self–organized complexity. In this sense, power law distributions are now interpreted as emergent properties of self–organized complex systems. These emergent properties have been widely observed to occur in frequency–size statistics, networks, and time series (Turcotte et al. 2002; Turcotte and Rundle 2002). To some scientists, the recurrence of power law patterns implicates the operation of deep, organizing principles that transcend the details of many living and non–living systems.

A classic example of power law scaling is the Gutenberg–Richter relation between earthquake size and frequency. There are many large earthquakes and far fewer large earthquakes, but there is no typical size for an earthquake. Nonetheless, despite the many geophysical variables that may contribute to earthquakes, quakes from a wide variety of contexts across the globe exhibit the same power law distribution. Similarly, the number–area distribution of planetary craters follows a power law distribution,
suggesting that there is no typical size for asteroid and meteorite planetary collisions, but some overarching process is regulating their overall size distribution.

Many different kinds of social, biological, and physical networks also exhibit power law distributions. Empirically studied networks tend to be composed mostly of nodes with a few links and have far fewer nodes with very large numbers of links. Real, complex networks also tend to be both scale–free and small–world networks. That is, the distributional pattern of nodes and links increases very slowly as network size increases but, at the same time, such networks are extraordinarily well connected. The shortest path between any two nodes is remains very small, even when millions or billions of nodes are connected (Newman 2000; Strogatz 2001).

Power law distributions are evident in the allometric scaling of many components of biological systems. These relationships are so consistent and pervasive that they transcend the fine–scale details of behaviors or physical traits. It now appears that allometric scaling emerges in biological systems because of their dependence on fractal–like energy circulation networks. Since landscapes may be networks in which social, biological, and physical systems participate, power law distributions may be a common feature of systemic and archaeological landscapes.
Landscape ecologists argue that landscape ecological processes are hierarchically structured. River and stream systems, for instance, are strongly hierarchical patch systems scaled according to microhabitats, habitats, reaches, segments, and networks (Poole 2002). In landscape hierarchy, fine–scale processes are constrained or guided by broader–scale processes (O'Neill et al. 1989). *Bottom–up trans–scale processes* can also occur, where fine–scale processes influence more coarsely scaled patch structures (Poole 2002). The hierarchical nature of landscapes suggests the need for multi–scalar analyses of landscape processes that investigate the relationship between archaeological patterns and inferentially related systemic processes. As landscape approaches continue to develop, investigators may formulate research problems in terms of the interplay between broad and fine–scales of analyses.

Ironically, some landscape approaches emphasize acquisition of high resolution data, obtained at fine scales, while others emphasize investigation of broad–scale processes. The two ends of this spectrum (fine–scale patterns to broad–scale processes) are likely interlinked in a variety of interesting ways worthy of investigation. How and to what degrees do broad–scale processes constrain or influence the formation of finer–scale patterns? How can fine–scale patterns be used to infer broad–scale processes? Do fine–scale processes influence the formation of broad–scale patterns?

Some domains of archaeological inquiry are amenable to these kinds of questions. Fine–scale patterns of people–material interactions as reflected in household inventories
(consumption), spatial patterns in land use and definition, or artifact densities can be related to broad-scale cultural processes such as globalization, political hegemony, or commodification or natural processes such erosion, climate change, or ecological change.

One promising avenue for identifying and investigating the influence of hierarchical processes on archaeological patterns is by aggregating archaeological data sets over large spatio-temporal scales. Owing to the nature of most archaeological data, such aggregations should be influenced by many uncontrolled variables. Methodological, behavioral, spatial, and temporal variability should produce a lot of noise, but the occurrence of large-scale patterns obtained through broad-scale, interregional comparisons can also be inferred to result from broad-scale processes that hierarchically exert control over finer-scale, regional, and sub-regional archaeological patterns.

*Environmental Constraints on Landscape Interaction*

Recent applications of a “landscape approach” to archaeological investigations could be criticized for simply using new terms to describe old methods. The term “landscape” is simply substituted for “environment” and offers no new insights into the human past or the archaeological record. This charge may, in large part, be true except that the term landscape generally carries with it a slightly more nuanced meaning. Landscape approaches, as applied to anthropology, allow for more recursive conceptualizations of human–environment interactions. Humans and their environments form feedback systems that create something formed recursively through the historical
(time transgressive) interaction of humans and environments – landscapes. Geographic concepts such the “built environment” fit nicely into such approaches.

Environment cannot be separated from landscape studies because it forms a crucial component of an essential form of interaction. The interaction between humans and their environments generates anthropogenic landscapes. Environment, here, is not conceptualized as a backdrop or substrate, but an elemental component of an interactive process – landscape formation. From a landscape perspective, environment is not deterministic of human behaviors. Human behaviors and environmental processes are mutually deterministic. More appropriately we might say that biotic and abiotic behaviors and processes are mutually deterministic.

The influence of environment on landscape formation is not minor. Environment does determine what basic resources (molecular structures, micronutrients, land forms, flowing water) are available for human interaction (cf. Milewski and Diamond 2000). In this sense, environments both constrain and enable the kinds of interactions and processes that can take place. The structural and chemico–physical attributes of environments constrain landscape formation processes. Humans, generally, do not have the opportunity to cultivate oyster pearls in a desert basin. Conversely, corn is not grown at the bottom of the ocean. Mountain slope, terrace farming is not likely to be advantageous on the Great Plains. Canals are not likely to be built on steep mountain slopes far from abundant water sources.

The strong influence of environmental factors on landscape formation processes is likely to cause confusion about determining factors. Humans are part of their
environment. Human behaviors are integrated into ecological systems. The culture versus nature dichotomy, in landscape studies, is simultaneously upheld and disassembled.

*Environmental Constraints on Australian Desert Landscapes*

Flannery (1997) argues, counterintuitively, that resource-poor Australasian environments help support the diversification of life. The uniquely diverse, evolutionary pathways of Australasian flora and fauna result from sets of environmental constraints (and thus contrasting sets of possibilities). The climatological, geographic, and geological history of Australasian landmasses has “set the stage” for subsequent biological evolution and evolutionary ecology.

The lack of major geological activity (e.g., volcanisms, glaciers) has made Australian soils a fossil resource. The availability of basic soil nutrients (e.g., phosphates, nitrates) is exceedingly low in Australia. Australian terrain is so flat and geologically quiescent that rivers appear to have maintained the same courses for millions of years. The availability of free water is low and erratic. Yet, Australia has very high species diversity, despite apparent environmental impoverishment.

One reason for the development of high species diversity could be because Australia has been so geologically and climatically stable. The lack of major environmental changes / upheavals has allowed for uninterrupted, long-term evolutionary development of ecological complementarity. The thick mantle of rock on which Australia rests is inferred to have shielded the continent from major volcanic events. The
flat terrain is inferred to have inhibited the development of rain–bearing meteorological systems. The northward drift of the continent in close coincidence with cooling climate is inferred to have maintained climatological stability over uncharacteristically long time scales (~ 60 million years).

Flannery (1997) argues that the low availability of basic environmental resources in Australia required organisms to specialize in particular ecological resources. Evolution, in Australasia, has selected against competition. Cooperative ecological systems are required to make environmental resources available. Organisms participate, rather than compete, in intensifying the cycling of nutrients. Carnivory and other high–energy biological systems are selected against. In Australia, environmental impoverishment has selected for energetic conservatism.

Hopping locomotion, for which kangaroos are so well known, is more energy efficient than running because it transfers potential energy to the tendons. Hopping also pulls the digestive system down, allowing the lungs to fill without energetic requirements of chest expansion. The extreme lethargy of koalas results from their nutrient–poor diet. Koala brains are so small that most of the koala cranial cavity is brainless. The breeding cycle of many Australasian organisms is very long and aperiodic in order to take advantage of brief, erratic periods of ecological fecundity.

What implications does this basic ecological, evolutionary trend have for human ecologies? Do humans generalize and compete when resources are abundantly available? Do humans specialize and cooperate when resources are scarce?
Landscape Configuration and the Sonoran Desert

Although Australian and North American Southwest deserts are similar according to some fundamental environmental properties (i.e., aridity), they are quite different in other respects. Both environments are arid, but have contrasting sets of environmental constraints on landscape formation processes. A fundamental property of the Sonoran Desert basin–and–range environment is its horst and graben geological architecture. Mountain ranges in the Sonoran desert subprovince of the Basin–and–range are generally linear, short, and trending northwest–southeast. A series of earthquakes during the late Tertiary and early Quaternary caused upward thrusting of block–faulted, sharp–crested mountains and simultaneous dropping of intervening valleys. The resulting geologic structure, referred to as horst and graben, is characterized by uplifted mountain pediments (horst) separated by basin fill sediments that are typically 1000s of feet thick. Basin sediments overlie down–faulted crystalline basement rock or graben (Ahlstrom 2000). The geological underpinnings of Sonoran desert physiography fundamentally organize the distribution of biotic resources, meteorological events, and ultimately exert powerful influences on the economic behavior of prehistoric inhabitants.

Unlike Australia, geological activity in the Sonoran Desert led to the formation of topographically prominent landscape features. These features bring nutrients to the soil, permit the formation of rain–bearing (though still erratic and occasionally catastrophic) weather systems, regulate the movement of water, and distribute ecological systems along elevational gradients. Although still a “harsh land,” these fundamental environmental constraints allowed (but did not necessitate) the emergence of agriculture
as a viable ecological strategy over 10,000 or so years of landscape interactions in the Sonoran Desert while agricultural behaviors are absent in Australia despite 40,000 or more years of landscape interactions.

The Bintliff–Snodgrass Model

An interesting example of landscape hierarchy is Bintliff and Snodgrass’ (1988) interregional investigation of off–site ceramic distributions. Their analysis proceeds from recognition of a fundamental archaeological problem: Why do offsite surface ceramics distributions in Boeotia, Greece form a virtually continuous, uniform carpet? In attempting to answer this question, they introduce and evaluate several models of archaeological landscape patterns which I define as: 1) the donkey model; 2) the use–intensity model; 3) the smear model; 4) the manuring model; and 5) the landscape hierarchy model.

The first (the donkey model) they dismiss easily as a folk model in that it stipulates the random loss of pots from the back of a mythical donkey that travels preferentially in the vicinity of sites, dropping pots along the way. Random loss is not a bad background model against which to compare observed archaeological patterns, but in their case it does not appear to fit the data.

The use–intensity model stipulates that artifact densities relate to the use–intensity of particular areas or zones, such that residential sites should exhibit relatively high artifact densities and less–intensively used offsite areas should instead exhibit lower artifact densities. Snodgrass and Bintliff (1988) argue that the use–intensity model is
applicable in some areas of the globe (e.g., Thomas 1973), but does not explain the uniformity of artifact densities in the Boeotian case.

The smear model “emphasizes the role of natural transport and post–depositional disturbance” (Bintliff and Snodgrass 1988:508). In the smear model, originally discrete concentrations of artifacts are smeared around by a variety of natural and cultural processes, resulting in a “halo” of artifacts around the original locus of human activity. They argue that the implicated processes should result in a relatively steep density gradient (as one moves away from sites) as well as a tendency for artifacts to be relocated downslope from their original locations. Moreover, they argue that smeared artifacts should be more weathered, having been subjected to greater degrees of disturbance and weathering processes. The lack of distributional bias towards downslope locations and no evidence for differential weathering in Boeotian ceramic carpets argues against the smear model.

Of the first four models, the model they believe is best supported by historical and archaeological evidence is the manuring model. In this model, fecal matter, organic debris, and trash containing sherds (Cherry et al. 1991; Wilkinson 1994) are redistributed across the landscape and plowed into the soil. They argue that manuring processes introduce a relatively uniform, continuously distributed subsurface repository of sherds. The manuring model explains the uniform, continuous distribution of ceramics but it does not explain (fully) why similarly broad ceramic distributions in Northwest European, Mediterranean, and Middle Eastern contexts have a huge range of average densities (.0008 to 3750 ceramics / 100 m²) when survey areas are compared.
Figure 7.1  The relationship between average annual rainfall (mm) and sherd density (sherds / 100m2) on a semi log plot. Filled squares are maximum offsite sherd densities for survey data compiled by Bintliff and Snoggrass (1988) for surveys in the United Kingdom, Mediterranean, and the Middle East. Maximum offsite sherd density for IFNM samples (open triangle) and average sherd density for IFNM sites (filled triangle) are included for comparison.

What does explain this broad interregional variation in ceramic densities is what I have called the landscape hierarchy model. The importance of Bintliff and Snodgrass’s (1988) approach is not so much that they implicate a behavioral process responsible for the formation of ceramic carpets, but that they compared these carpets inter–regionally. Without their interregional comparison, we might interpret the surface artifact densities of ceramic carpets to imply variation in behavioral processes such as the intensity of
manuring, rates or longevity of ceramic production, artifact use life, population density, or consumption. In comparing offsite ceramic densities from surveys in the United Kingdom (Roman Essex, East Hampshire, and Maddle Farm [Berkshire]), the Mediterranean (Southern Italy and Boeotia, Greece) and the Middle East (Tell Sweyhat, Syria and Sohar, Oman) Bintliff and Snodgrass (1988) show that sherd densities increase sharply along a gradient from Northwest Europe through the Mediterranean to the Middle East. Using average rainfall as a proxy for erosion, they show that interregional variation in climate and erosional regimes exerts a strong influence on the variation in surface artifact densities (Figure 7.1). Despite the fact that their data are represented by single-period and multi-period artifact scatters in separate regions surveyed according to a variety of different methods, the interregional pattern is clear. In other words, despite the many contextual details of individual surveys, regions, and culture histories a broad-scale pattern emerges.

Although variation in population levels, land use intensities, and artifact life histories likely occurred both intra and inter-regionally, broad-scale environmental processes exert hierarchical controls over archaeologically observed patterns. In semi-arid areas, subsurface pottery is increasingly exposed through wind and water erosion, while in temperate areas subsurface pottery is hidden from view by burial processes. This archaeological pattern is only apparent when comparing properties of archaeological landscapes across very broad areas.

Simply as a point of comparison, I include data from the IFNM survey in a semi-log plot of survey data compiled by Bintliff and Snodgrass (1988). Maximum recorded
offsite sherd densities were estimated in a manner identical to the Boeotian survey. Individual transect lines (within quadrat samples) were assumed to scan a 5–meter–wide sample window. Offsite sherd densities, calculated as sherd frequency divided by scanned offsite area were then multiplied by 4 to account for a 20 meter sampling interval. Not surprisingly, IFNM offsite sherd densities clearly fall well below those expected for the relationship observed in Europe and the Middle East. While the aridity of southern Arizona should be characterized by generally comparable erosional processes, neither plowing nor manuring is known to have occurred in modern or prehistoric times in sampled areas of the IFNM. Artifacts have not likely been continuously redistributed across the archaeological landscape through plowing and manuring behaviors. Instead, artifacts may have been subject to natural and post–depositional redistributive processes like that of the smear model described above.

Oddly, the IFNM average onsite ceramic sherd density falls comfortably within the relationship in Figure 7.1. Mean onsite sherd density was estimated from random 1 m$^2$ and 4 m$^2$ onsite density plots. While this measure is not the same as the offsite measures (it is an average from sites and not a maximum from offsite contexts), it is curious that it fits into the pattern. As we shall see in another chapter, there is no characteristic density for onsite sherds in the IFNM, so summarizing sherd densities with an arithmetic mean is inappropriate. The greater the number of samples, the more likely that the mean would be higher as density plots with high density (relatively rare according to the power law) would continue to be added to the distribution.
CHAPTER VIII — MODELING SYSTEMIC LANDSCAPES OF THE IRONWOOD FOREST NATIONAL MONUMENT

Introduction

Systemic landscapes of the Ironwood Forest National Monument (IFNM) are here modeled as series of evolving landscape networks. Imagine constellations of places arrayed across the land, each connected by routes of travel. These networks are heterogeneously arrayed over landscape surfaces hosting different availabilities of targeted resources – game, tool stone, plants, potable water, livestock forage, ore bodies, etc. As time progresses, new places are added to networks while others are removed. Routes between places are established, others maintained or altered, while still others fall into disuse. People and groups circulate throughout these networks, procuring, processing, consuming, transporting, and depositing materials.

Over time, the availability and quality of targeted resources changes across landscape surfaces. Local demographics also change. Some households move away, others are created, some suffer catastrophic loss, others prosper. Resources in some areas become unexpectedly prodigious, in others they decline or become unpredictable. People respond to changes in the perceived availability of resources and to the needs of group members, making strategic decisions about where to conduct present and future activities. The kinds of resources targeted may also change. Changing conditions may alter the matrix of strategic options, resulting in the pursuit of new or different resources or the development of new strategies for resource acquisition.
The duration, frequency, and intensity of place use will likely vary as people respond to fine-scale variation in resource availability and selectivity. Characteristics of the network will probably also change as well. As place use changes, routes between places may change to reflect altered flows of people and materials. Larger networks may break up into smaller, disconnected networks; smaller networks may link up with larger networks. Some places attract redundant use, acquiring increasing prominence in landscape networks. Other places may be the focus of important events or circumstances, becoming stable by virtue of how groups remember them. Other places are more transient, being used only one or a few times and perhaps re-appearing in later networks for totally different reasons.

While major network perturbations and reorganization can and do occur, it is easy to see that systemic landscape networks can be in a constant state of flux, continuously responding to fine-scale variation in environmental and cultural conditions. Such networks may be far from equilibrium but, in the absence of major perturbations, could fall into relatively stable basins of attraction (for discussions of complexity theory in anthropology see Lansing 2003; McGlade 2003). Relatively stable, unperturbed networks could produce enduring patterns of networked activities.

Places that are used redundantly could retain long-term prominence in landscape networks, possibly attracting increased use through time. Thus, prominent places could be subject to phenomena like the “rich get richer” effect, attracting connections to other places and activities in a manner similar to small-world networks. Major perturbations, however, could initiate major reorganizations of network topologies. Major places may
become abandoned and new places established. The functions of places may likely change as well. Earlier residential locations may be mined for abandoned tools and materials or serve as waypoints in spiritual, generative cartographies. Previously minor locations may swell as groups establish new residential locations or co-reside with existing groups.

Emically recognized places may converge on previous places as a result of accident or design. Moreover, places with enduring qualities (i.e., access to water, views, alluvial sediments) may have greater capacity to attract use. It is difficult to discern whether an archaeologically recognized place was an enduring node in a long-term landscape network or a node in many landscape networks. In order to infer the functions of a place within a settlement system, we have to assume that such a place was part of a singular system and that the archaeological elements used to interpret function are not elements from separate systems. Further, we have to infer that apparently contemporaneous places are actually part of the same system, when they could be components of the same, related, or unrelated functional systems.

The Sierra Piñacate archaeological landscape is an example of a composite of systemic landscape networks operating over very long periods. Owing to the extreme aridity of the region and the spatial scarcity of water, circulation throughout the Sierra Piñacate is organized by the locations of tinajas (natural water holes). In the Sierra Piñacate, tinajas are connected by a vast system of trails. Many of these trails lead away from the Sierra Piñacate, connecting archaeological regions in all directions.
Many of the nodes in this network are surprisingly well connected. Rather than connect to two or three other places, trails commonly lead off in four or five directions. One gets the impression that these trail systems, while anchored to *tinajas*, allowed large portions of the Sierra Piñacate to be accessed. Although the availability of water may have enhanced the local abundance of game at *tinajas*, *tinajas* may also have functioned as the means to allow access to other unwatered areas of the landscape.

The geomorphic stability of landscape surfaces and spatially discrete water sources in the Sierra Piñacate fossilized portions of prehistoric and historic systemic landscape networks into an amalgamated, archaeologically visible network. Although not represented on this map, Hayden was able to distinguish the relative ages of Sierra Piñacate trails through a variety of inferences. Some trail segments are intersected by natural disturbances, requiring new segments to be created. Some trails intersect earlier features or are marked by cairns with variable degrees of weathering and desert varnish formation. Sierra Piñacate sites and trails also yield archaeological materials from diverse time periods.

Due to the extreme aridity of the region and summer heat of the region, no group likely resided in the Sierra Piñacate full time. The Sierra Piñacate was probably used intermittently by groups accessing adjacent regions (Heilen 2001, 2004). Many different landscape networks may have participated in the formation and use of the Sierra Piñacate trail system. The Hohokam may even have used portions of the trail system to access the coast for salt and marine shell.
The Sierra Piñacate archaeological landscape appears as an integrated system of *tinajas* connected by trails. The visibility of this network is enabled by the largely two-dimensional nature of Sierra Piñacate archaeological manifestations, resulting in a palimpsest of systemic landscape elements. The overall network of places and trails is probably one of remarkable duration, yet we have to conclude that the archaeological landscape represents the end–product of an evolving and changing network or series of networks.

The modeling of systemic landscapes that incorporated portions of the IFNM at different times in the past must be pursued with similar caution. We cannot recover the actual living network, but only infer signs of its potential organization. Even if different places in a functional network can be argued to have had discrete functions, variation in place use over time leads to mixed and overlapping indicators of function.

Archaeologically visible places, moreover, are made visible by virtue of characteristics of the environment as well as by behavior. Particular features of Sierra Piñacate climate and geomorphology allow portions of prehistoric systemic networks to endure for long time periods as well as allow an overall network of prehistoric trails and sites to be archaeologically visible.

In this section, I present a series of models of systemic landscapes of the IFNM. I place heavy emphasis on models derived from historical, ethnographic, and modern contexts because such contexts can provide more detailed information about how people interact with landscapes. What this series of models shows is that different modes of production require different forms of landscape cognition and utility. Both the
characteristics of environments and strategies for exploiting environments converge in a landscape to form the landscape.

An interesting aspect of these systemic landscape models is that they are progressively connected to larger and larger networks over time. Landscapes of desert and riverine adaptations, while treated as separate models, are interconnected networks of activities. Materials and labor are exchanged between these networks and thus may form a larger bifurcated network. During the Spanish Colonial period, a network of presidios and missions was established throughout portions of the Southwest, connecting local indigenous groups to larger colonial networks. Interestingly, while exploration of the potential riches of the region was involved in colonial processes, much effort was placed on infecting local populations with cosmological principles and land use systems consistent with European normative values. Santa Ana de Cuiquiburitac, a Spanish visita in the Aguirre Valley (southwestern corner of the IFNM), was at the frontier of the mission system, intended to link up with a group of indigines who themselves were at another kind of behavioral frontier, that between desert and riverine adaptations.

Tohono O’odham Landscapes

The western and southern boundaries of the IFNM adjoins the Tohono O’odham reservation boundary. Historically, the IFNM likely formed part of a permeable boundary between Tohono O’odham and Akimel O’odham settlement systems. In historic (and probably protohistoric times), resources of the IFNM were probably
exploited by Tohono O’odham, Akimel O’odham, and the Kohatk (an intermediate group).

A desert – as opposed to riverine – people, the Tohono O’odham live in some of the hottest, driest reaches of the Southwest, a vast area of inland desert referred to as the Papaguería. In contrast to the Tohono O’odham, contemporaneous Akimel O’odham lived along large, perennial drainages watered from distant, extralocal sources that permitted the application of intensive agricultural practices such as irrigation and double or triple cropping (Rea 1997).

Areas of the IFNM, the backbone of which are several interconnected mountain chains (the Roskruge, Waterman, East Silverbell, West Silverbell, and Sawtooth Mountains, Figure 8.1), form a sort of interface between areas traditionally exploited by both desert and riverine groups. It is thus conceivable that areas of the IFNM form a kind of cultural–ecological transition zone between both lifeways. Interestingly, this transition is exemplified by an O’odham group called the Kohatk whose “cultural ecology was intermediate between that of the River People and the Desert People” (Rea 1997:9). The Kohatk are historically known to have resided during the summer in field rancherías in the Aguirre Valley (within the IFNM) near the Spanish visita Santa Ana de Cuiquiburitac and in the Santa Rosa Valley (west of the IFNM). Other parts of the year they moved to areas along the Gila.
The Tohono O’odham exercised seasonal residential mobility, moving between summer field camps or villages and winter well camps or villages. As such, Tohono O’odham families maintained two separate households, each with duplicate sets of storage, cooking, and grinding equipment. Tohono O’odham households tended to rely on basketry for storage, but also made some pottery. At winter well camps, women are reported as gathering wild plant foods and raw materials and manufacturing pottery.

**Figure 8.1** Map of major physiographic features described in text, centering on the IFNM (the large irregular polygon).
vessels and basketry while men hunted in nearby mountains (Castetter and Bell 1942; Underhill 1939).

Like the Akimel O’odham, Tohono O’odham lived in large (1 to 2 km in extent), highly dispersed, low density settlements composed of numerous rancherías (Darling et al. 2004). Each ranchería can be interpreted as a single extended family or household. Tohono O’odham rancherías consisted of a residential structure, one or more ramadas, a variety of storage units (built in a similar fashion to residential structures), and a menstrual hut. Although later Tohono O’odham houses tended to be made of adobe, earlier houses were generally constructed of organic materials: mesquite or ironwood timbers, saguaro ribs, ocotillo withes, soapweed (Yucca glauca) or agave (Agavaceae) fiber cordage, creosote bush, and heaped earth (Castetter and Underhill 1935).

While some exceptions likely occurred, the majority of Tohono O’odham agriculture was ak chin, or floodwater farming. The Tohono O’odham grew a variety of domesticated plants (including Spanish introductions), including legumes (tepary, kidney beans, vetch, lentil, chick peas), corn, cucurbits (pumpkin, cushaw, muskmelon, watermelon), tobacco (coyote tobacco, Yaqui tobacco), cotton, and wheat. Cotton is thought to have been grown only minimally by the Tohono O’odham. Though the Tohono O’odham kept dogs and some bird species as pets (and perhaps as security), the use of domesticated animals for food, transportation, and field work occurred only with the introduction of horses, cattle, sheep, and goats by Spanish missionaries (Castetter and Underhill 1935).
In addition to agriculture, Tohono O’odham obtained food and raw materials from a wide variety of plants and animals. Tohono O’odham hunted both large (mule deer, white-tailed deer, antelope, mountain sheep, wild turkeys, and possibly peccary) and small (black-tailed jackrabbit, white-tailed jackrabbit, cottontail rabbit, packrat, round-tailed ground squirrel, Merriam pocket mouse, kangaroo rat, Gamble’s quail, and morning dove) game. Hunting was generally performed by boys and men using bow and arrow technology. Despite reliance on a wide variety of small game, trapping was uncommon. Annually Tohono O’odham men and boys performed large rabbit drives. Deer hunting was performed by small, specialized, winter hunting parties that stocked up skins, sinew, and fat some of which they traded to other groups (Castetter and Underhill 1935). The meat of most large game was sun-dried.

Most Tohono O’odham food was made from “dried foods: cereals, dehydrated vegetables, and sun-dried meat” (Castetter and Underhill 1935). The major foodstuff, flour, was processed from a variety of wild and domesticated seeds (mesquite, ironwood, palo verde, yucca, saguaro, wheat) and generally incorporated into a kind of gruel made with boiled dehydrated vegetables. Many vegetables (cholla joints, squash, agave flower stalks) were processed by pit roasting. Other gathered and cultivated food resources (root crops, cultivated squash, beans) were sun-dried. Highly prized, sweet cactus fruits (i.e. saguaro and prickly pear) were often stored as dried product or processed into jams and syrups.

Like many other indigenous groups that live close to the land, the Tohono O’odham survived on a wide variety of plant, animal, and mineralogical resources.
Although they certainly performed extensive agricultural practices, they were seasonally mobile, and obtained much of their food and raw materials from wild and semi-domesticated sources. In addition to seasonally occupying field and well camps, they also maintained cactus camps, where they would gather Saguaro fruits before the first summer rains. The Tohono O’odham were thus residentially and logistically mobile within some territorial constraints. Most of their resources were obtained at the household and community level, but they also carried on some exchange with groups involved in Riverine cultural ecologies.

As Tohono O’odham became more integrated into Spanish, Mexican, and finally American administrative structures, residential and economic patterns came under the influence of larger political-ecological structures. They obtained greater numbers of cattle and horses, participated to greater degrees in cash economies, resided in stable locations centered on government wells, used roads and facilities funded by extralocal resources. As they became “reservationized” their landscape interactions changed. They were less residentially mobile, but more logistically mobile. They obtained subsistence resources increasingly through exchange. They depended on livestock that altered vegetation and competed for forage with other game animals. Tohono O’odham landscapes were integrated into larger socio-ecological landscape networks with structures that differed from those of their historic predecessors.

Likewise, the kinds of landscape interactions that preceeded those of the historic Tohono O’odham were also quite likely different than those observed historically.
Akimel O’odham Landscapes

Rea (1997) describes the Akimel O’odham landscape in geomorphological and ecological terms. Akimel O’odham landscapes, collectively referred to as *jeved kaachim* (earth remaining there) are divided into three major units: 1) floodplains or level lands (*s–sheliŋ jeved*); 2) bajadas or foothills (*to’otonk*); and 3) mountains (*do’ag*). As loci of agricultural production, residential settlement, surface water, and wild plant and animal procurement, floodplains are elaborated domains of landscape terminology. Floodplains are subdivided into lower and upper terraces. Lower terraces are composed of several important ecological settings: 1) mesquite bosques (*s–kuik*); 2) riparian woodlands (*s–a’uppak*), and 3) grasslands (*s–vashaik*). Floodwater agricultural fields are referred to as *oidag*.

The importance of water to personal sustenance and agricultural production no doubt led the Akimel O’odham to classify different kinds of water sources: 1) large perennial washes or rivers like the Gila River (*meldadam*); 2) large, more ephemeral, sporadic, or seasonal washes with tributaries like the Santa Cruz River (*vo’oshañi*); 3) springs or primary streams (*shongam*); 4) seeps (*s–va’uandam jeved*); 5) salt flats (*ongam*); 6) large lakes (*hejelko shuudagi*); 7) constructed water ponds or charcos (*vachkî*); and 8) the ocean (*kaachkî*) (Rea 1997). In essence, the Akimel O’odham classified some basic landscape elements according ecological resources, in terms of how they get food and other resources.
The Kohatk are a distinct O’odham group that historically occupied areas within and adjacent to the IFNM. Though they have received minimal attention in historical records and anthropological literature, the Kohatk likely formed a crucial link between Tohono O’odham, Akimel O’odham, and Spanish missionaries during the Spanish Colonial and Mexican periods. The feature of Kohatk lifeways that has received the most attention is their settlement and subsistence patterns. As the Kohatk are reported to have occupied summer field villages in the interior Papaguerían desert and winter villages along the Gila River, Kohatk settlement and subsistence patterns are characterized as intermediate between Tohono O’odham and Akimel O’odham settlement and subsistence patterns.

The Kohatk, in this sense and others, are an anthropological chimera. Just as there has been nearly as many spellings of the term “Kohatk” (Fontana 1987; Hackenberg 1974; Jelinek this volume) as there are discussants of the Kohatk, there is considerable confusion over the desert or riverine status of Kohatk ecological behaviors and ethnic affiliations (Whittlesey et al. 1994). As a witness for the defense in *Gila River Pima–Maricopa Indian Community et al versus The United States of America*, Hackenberg (1974:287) argues that Kohatk are Papago (Tohono O’odham), but later writes that “there is no more reason to classify the Kohatks with the Pimas for any purpose whatever than there is to classify them with the Papagos.” Russell (1908) and Lumholtz (1912) both describe the Kohatk as Pimas (Akimel O’odham). More accurately, Ezell (1955)
identifies the Kohatk as occurring along a continuum between Akimel O'odham and Tohono O'odham but at the same time inconsistently affiliates Kohatk with either group (Hackenberg 1974).

Variants of indigenous groups now described as O'odham are categorized as Hia C’ed O’odham (Sand Papago), Tohono O’odham (Desert Papago), and Akimel O’odham (River Pima). Although a variety of subsistence strategies are shared between these groups, one important variable that distinguishes the three groups is residential mobility. Akimel O’odham are “One Village People.” Tohono O’odham are “Two Village People.” Hia C’ed O’odham are “No Village People” (Whittlesey et al. 1994). Though certainly engaged in a variety of other forms of mobility (e.g., logistic mobility, household mobility, individual mobility), Akimel O’odham were residentially sedentary, maintaining residences in the same village year round. Tohono O’odham moved residences on a semi–annual basis in response to the local availability of water. As such, the Tohono O’odham traditionally maintained two separate residences – a summer field village and a winter “well” village.

Unlike the Tohono O’odham and Akimel O’odham, who depended on agriculture (as much as ~ 50%) for a significant portion of their subsistence (Castetter and Bell 1942; Hackenberg 1974; Russell 1908; Underhill 1939), the Hia C’ed O’odham performed only limited horticulture / agriculture. Instead, the Hia C’ed O’odham relied primarily on wild plants, game, and coastal resources. As Hoover (1935:261-262) observes:

For food the Sand Papagos ran down jack rabbits in loose sand, killed mountain sheep, mule deer, and antelope with bows and arrows, and caught muskrats. They ate lizards, and at certain seasons went to the coast to fish and to obtain salt. Only
a single agricultural site has been attributed to these people…Their vegetable food was largely the camote, an edible root found in the sand dunes, together with the beans of the mesquite and the fruit of the saguaro and pitahaya cacti…

Hia C’ed O’odham responded to continuously fluctuating availabilities of various untended resources, requiring constant shifting of temporary residences. As a result, Hia C’ed O’odham ranged over huge areas, covering ground that included Ajo, the Growler mountains, Sonoita, the Sierra Piñacate, and the Gulf of California coast.

Residential behaviors of major kinds of O’odham occur along a broad spectrum of residential mobility. Hia C’e’d O’odham are characterized by high residential mobility. Tohono O’odham are semi–annually residentially mobile and Akimel O’odham are sedentary. Like the Tohono O’odham, the Kohatk are “Two Village People”, but instead of residing in winter well villages, they reside in riverine winter villages.

Despite overall patterns of residential stability, the Tohono O’odham, Akimel O’odham, and the Kohatk (like the Hia C’ed O’odham) ranged over huge areas. Due to relative residential stability, much Tohono O’odham, Akimel O’odham, and Kohatk mobility is logistically organized. All three groups obtained biotic and abiotic resources from a wide range of places and many of these materials were transferred between other places including residential villages (Figure 8.2). Individuals, households, and specialized work parties traveled to different places to procure and process one or more resources. Some of these resources and / or their processed byproducts (i.e. roasted and dried plant foods, wood, tool stone) were transported to home villages or exchanged with
Figure 8.2 Historic hunting, gathering, fishing, and abiotic procurement places of the Akimel O’odham and Maricopa. Residential villages were confined to riverine locations within the current reservation boundaries. Reported in Hackenberg (1974) and Castetter and Bell (1942) field notes.

members of other villages through a variety of mechanisms such as ceremonial offerings, competitions, gambling, gifting (e.g. Underhill 1938).

Just as people, materials, information, and energy circulated dynamically throughout broad O’odham landscapes, village residence was also dynamic. Individuals, households, and whole villages moved to other villages on a fairly regular basis. Some
villages fell into temporary or permanent disuse while others experienced temporary population increases. Often, households from one village responded to variation in resource availability or intrusions from hostile groups by co–residing with other villages or sharing village affiliated resources (i.e. agricultural fields.) In addition, many villages in the Papaguerría are derived from parent villages, resulting in patterns of ceremonial relationships centered on parent villages (Hoover 1935)

In addition to settlement pattern, a number of other consistently recorded attributes distinguish the Kohatk from their Akimel O’odham and Tohono O’odham neighbors. The Kohatk were renowned for their excellent pottery (Curtis 1908; Hodge 1912; Hrdlicka 1906; Moore 1902; Russell 1908) and fine basketry (Curtis 1908; Moore 1902), made yucca stalk arrows (Hodge 1912; Russell 1908), used arrow–bush paint brushes (Russell 1908), dug reservoirs or charcos to store water (Ezell 1955; Fewkes 1912), and were fierce warriors (Joseph et al. 1949). The Kohatk traded their pottery, basketry, and yucca stalk arrows to Akimel O’odham, and probably to Tohono O’odham as well. These attributes highlight the behavioral linkages between Kohatks and neighboring groups and helped to establish the connectivity of the Kohatk landscape network with other Akimel O’odham, Tohono O’odham, and Apache groups as well as with Spanish missionaries. The Kohatk traded with and worked adjacent to neighboring groups, joined with other villages on the warpath against Apache intruders, and courted linkages with Spanish missionaries by laboring in agricultural fields of San Xavier del Bac and accepting the establishment of a visita at Santa Ana de Cuiquiburitac.
O’odham Landscape Networks

One approach to modeling O’odham landscapes that accounts for complex behavioral and material interactions between different social units across vast areas but also allows analytical simplification is as landscape networks. In Figure 8.3, a small portion of an O’odham landscape network is illustrated. These segments of the network connect a variety of different places visited over the course of a series of related events conducted by people from the Papaguerían village of Santa Rosa between 1850 and 1851. People (warriors, households, a kidnap victim), materials (food, personal gear, scalps), energy (labor), and information (word of Apache attack) are exchanged throughout these networked places across bidirectional and unidirectional pathways.
Figure 8.3 A network representation of activities recorded on the San Xavier del Bac calendar stick for a series of related events in 1850 (Underhill 1938).
When modeled in this way, a number of features of the network are particularly striking. Vast areas are traversed in the course of food–getting activities and social interactions. Linkages between places are formed by different social units and identities moving between different places at different times – households, warriors, young children, a Mexican informant. Food and materials are exchanged between people and places through a variety of mechanisms. Despite the relative complexity of people–people and people–material interactions occurring across these network segments, only a small portion of much larger landscape networks is here represented. The common denominator of all these activities is that households from Santa Rosa left their village with personal gear and desert plant foods and returned some time and many activities later with personal gear and agricultural plant foods (Underhill 1938).

**Historical Landscapes of Exploitation**

Dominated by low–lying hills and mountains, the IFNM is host to numerous geological and mineral resources (Ferguson et al. 2000b; Ferguson et al. 2000a; Ferguson et al. 2000c; Harris and Trapp 2000; Skotnicki and Pearthree 2000). Historic and modern mining in the area has been widespread and commonplace (Figures 8.4, 8.5, 8.6). Historic mining activities can be interpreted as linkages between local, regional, and global economic systems, often involving differential patterns of labor exploitation, political struggles and diverse sets of landscape interactions. As such, studies of historic mines and mining camps are an important focus of historical archaeology, aiding in the investigation of relationships between ethnic groups, economic classes, and regional and

Landscape–scale investigations of mining activities in southern Arizona have revealed two distinct patterns of settlement, “one dispersed and heterogeneous, and one clustered and apparently homogeneous” (Gillespie and Farrell 2002). Single, nucleated mining communities result from geographic concentrations of resources (i.e. water, wood, ore bodies, processing plants) that permit the performance of the vast majority of mining activities at a single location. However, given the sparseness of critical resources, such nucleated mining communities are comparatively rare in southern Arizona; as a result, dispersed and heterogeneous mining communities are considered more common (Gillespie and Farrell 2002).

Historic mining in the Silver Bell Mining District may have begun with copper mining at the Old Boot Mine in 1865, but small–scale opportunistic operations in the general area could conceivably have an earlier history. Nonetheless, historical development of mining in the Silver Bell Mining District encouraged the development of small mining camps (i.e., Peltonville), the growth and prosperity of the town of Silverbell, the construction of a smelter at Sasco, and the operation of the Arizona Southern Railroad for the transportation of ore from Silver Bell mines to Sasco and passenger service between the town of Silverbell and Red Rock (Slawson and Ayres 1994). As mining activities in the Silver Bell Mining District demonstrate, historic
mining within the IFNM resulted in diverse sets of spatially dispersed archaeological features now requiring evaluation and management. Mining activities also appear to have been commonplace in the Sawtooth, Waterman, and RoskrUGE Mountains as well as in nearby mountainous areas outside IFNM boundaries.

Historic period artifacts and features observed during the IFNM survey include metal food cans, tobacco cans, glass bottles, possible tent platforms, roads, trails, and surface mine extractive features. An interesting feature type encountered mainly to the
Figure 8.5 Mines in the vicinity of the Silverbell Mountains, Arizona.

north and east of the Silverbell Mountains is axe–cut trees. In one case, an axe–cut ironwood tree was associated with recreational artifacts (tobacco cans, liquor bottle fragments). It is tempting to interpret this refuse as the result of smoking and drinking during an episode of resource extraction. In any case, axe–cut trees may relate to the procurement of wood (for fence lines, construction, fuel) for historic period ranching and mining activities.
Figure 8.6 Mines within the vicinity of the Waterman and Roskruge Mountains, Arizona.

Historic period archaeological finds range from a single metal artifact or cairn, to a complex of interrelated mining features and artifacts (i.e., mine shaft, trail, cairn, tobacco can, wood beams, ore piles), or scatters of metal artifacts interpretable as trash dumps or scattered refuse. In general, we can interpret these features as reflecting networks of mining-related activities. Local networks are composed of mines, mining claims, labor camps, and extractive locales connected by roads, trails, and railroad lines.
These comprise a local landscape network system that enables the transfer of people, materials, and energy between places within local zones of extraction. Agents in this local network are operating at relatively fine scales, responding to variations in topography, vegetation, geology, etc.

What is interesting about this local landscape network is that its linkage to larger political economic networks. In addition to indigenous populations, the labor force draws on immigrants from distant parts of the United States, Mexico, Europe, and China. People of heterogeneous historical and ethnic backgrounds circulate throughout this network. Moreover, many consumable items are drawn from distant sources. The reach of network connections is reflected in the provenance of what is consumed: labor, food, and tools. While labor, materials, and products of manufacture are consumed locally, network exchanges occur on an almost global scale. Labor, goods, and capital flow into local mining networks and raw materials flow out of them.

*Notes to Chapter VIII*

1 – The events modeled in this network come from an account of events on the San Xavier del Bac calendar stick. While many related activities may be excluded in the description and some aspects of the description may be distorted through the transmission and remembrance of oral history, the account does provide an interesting example of how different kinds of matter, energy, and information can circulate between places within a landscape network. While a variety of other manifestations of matter, energy, and information were likely exchanged between places and a variety of other places were
likely accessed by Santa Rosa villagers during this time period, only those that can be reasonably inferred from the description are included. The account is as follows:

1850–51—In the autumn, the people from Burnt Seeds [Santa Rosa] came to the Hollow Place [San Xavier del Bac] to hold a Skipping Dance.\(^3\) When it was over, a Mexican came from the Foot of the Black Hill [Tucson] and said that there were Enemies [Apaches] there. So all went and fought the Enemy.\(^4\) They killed some of them and the killers remained for four days’ purification. When the four days were over, they returned to the Hollow Place and held a scalp dance. Now the Hollow Place wanted to sing for the Burnt Seeds and be paid in turn. But the Burnt Seeds people were going to Sonora to work for the winter, so they said that instead of being sung for at home they would bring their food back to the Hollow Place, which was on their way to Sonora. They went home and collected stores of cactus seed, cholla joints, and dried Spanish bayonet fruit \(Yucca Baccata\) and brought them to the Hollow Place. The people of the Hollow Place sang for them and were given the food and then the Burnt Seeds people went to Sonora. All of them went, men, women, and children [households], and they took all their property [personal gear]. They harvested for the Mexicans and earned corn and beans to take home. After the harvest, they all started home again and got as far as Rotten Ground [Covered Wells]. Just beyond there, they camped and saw Enemy tracks. So they left the women in camp and followed. They came up with the Enemies behind Black Hill [west of Tucson] and there they fought, and Take–a–Horse killed another Enemy. The Enemies had with them a child whom they had stolen at Mountain–Tied–in–the–Middle [Baboquiviri] and during the fight the child hid under some straw. When the fight was over he ran home. The men went back to camp, got the women and all went home to Burnt Seeds. There they had four days’ purification for the killer and then the scalp dance (Underhill 1938:20-21.)
CHAPTER IX — SITE SIZE AND ARTIFACT DENSITY: METRIC PROPERTIES OF ARCHAEOLOGICAL LANDSCAPES

Archaeologists lacking text or memory must infer systemic landscape properties from archaeological landscape properties. Middle range theory is used to model how archaeological and systemic landscape properties are related. Advances in complexity theory and mathematical graph theory underscore the importance of power law statistics in the investigation of broadly-scaled, global phenomena. Hierarchy theory suggests that broadly-scaled, landscape-level phenomena may exert controls over many lower-level phenomena. It is also possible in some cases that complex, global phenomena emerge from the simple interactions of lower-level processes. Fractal theory suggests that simple growth processes may cause landscape patterns to be related (have similar fractal dimensions) across broad ranges of scales.

Two basic dimensions of archaeological landscapes are site size and artifact density. Patterning in these dimensions may relate to fundamental processes in behavioral systems and thus are often monitored in terms of other potentially related variables (i.e., levels of organization, environment types, tool class use lives). Site size and artifact density may also relate to each other in a number of important ways.

A basic problem with analyzing site size and artifact density is that the two variables are seldom — if ever — normally distributed. Consequently, the use of average statistics may be inappropriate to analyzing relationships between site size, artifact density, and other variables. Previous work on settlement size distributions suggests that settlement sizes are often distributed according to Zipf’s (1949) law (Brown and
Witschey 2003; Brown et al. 2005; Laxton and Cavanagh 1995; Zipf 1949). That is, settlement rank often scales to settlement size according to an exponent of \( \sim -1 \). As a consequence, settlement systems are often composed of a few large places and many small ones. Similar distributions are found in real world, hierarchical networks. Hierarchical networks are often composed of a few highly connected nodes and large numbers of more weakly connected nodes (Buchanan 2002; Hastings and Kozma 2004; Newman 2000, 2003; Watts and Strogatz 1998). Similar power law or fractal relations are found in archaeological distributions. Brown et al. (2005) obtained similar fractal dimensions (\( \sim 1.26 \)) for artifact distributions mapped by Binford (1978) at the Mask site, a Nunamiut campsite in Alaska and the Barmose I, and early Mesolithic site (Blankholm 1991).

The fractal dimensions of artifact distributions at a systemic place and an archaeological site are both similar to that created by the Cantor Square, a fractal pattern resulting from the Cartesian division of larger squares into smaller squares by a simple rule. To Brown et al. (2005) this suggests that archaeological distributions may often consist of complex clusters within clusters an observation also made by Ebert (Ebert 1992). Thus, it may be the case that artifact density and site sizes are related by fractal growth processes. It may even be possible that these same fractal growth processes extend to larger–level archaeological patterns.
The IFNM can be described as an archaeological landscape. The IFNM is a contiguous surface over which archaeological materials are arrayed in a variety of contexts. How we define the boundaries and extent of this landscape is more or less arbitrary. The IFNM administrative boundary could contain the landscape as a particular entity of bureaucratic control. Or it could be the archaeological landscape as defined by one or more valleys, depositional contexts, or material categories. A simple way to conceptualize an archaeological landscape is as a continuous array of spatially distributed attributes that contribute to the character of the archaeological property or area under study.

This definition of an archaeological landscape has certain advantages in that it limits assumptions about the relationship of archaeological landscape materials and contexts to systemic conditions and contexts. Properties of the archaeological landscape can be monitored without explicit reference to functional and temporal interpretations of archaeological data, in a manner similar to Sullivan and Rozen’s (1985) “interpretation-free” observational categories. By considering the archaeological landscape as a phenomenon distinct from, but not unrelated to, systemic landscapes, we can make more objective statements about the fabric and constitution of archaeological landscapes before resorting to inferences on specific forms of behavior. Thus, we limit our assumptions about the influence of different kinds of archaeological landscape formation processes.
Monitoring basic properties or dimensions of archaeological landscapes could help researchers identify major influences on archaeological patterns. Broad-scale patterns could indicate the presence of high level, hierarchical controls on archaeological landscape phenomena. Alternatively, scale-invariant fractal growth processes may allow both broad-scale and fine-scale processes to have similar properties. If we want to investigate differences in site size between different time periods, site types, or environmental zones we will want to know how site sizes are distributed.

A common concern for archaeologists is how basic properties of sites vary with environmental variables. In the basin–and–range province, ecological resources tend to be distributed according to vertically differentiated environmental zones. As a result, activities may vary along vertical gradients corresponding to basic landform types: mountain slopes, upper and lower foothills or bajadas, proximal and distal floodplains, valley axes. We might also expect these same zones to have different sedimentary histories. Except in colluvial areas, upland settings are eroding or stable while floodplains are aggrading. For areas like the IFNM, elevation is not a particularly good proxy for this environmental zonation because at a larger level, the physical landscape is decreasing in elevation along a southeast–northwest gradient. Mountain slopes in one location may be similar in elevation to upper bajada settings in another. In order to develop a proxy for environmental setting for the IFNM archaeological landscape, I assume that the watershed boundaries for major hydrological units such as Avra Valley and Aguirre Valley generally correspond to the backbone of major mountain chains. Major streams such as Brawley Wash and Aguirre Wash I interpret as valley axes.
Conceptualized in this way any location within the IFNM can be quantified in terms of its relative position to either watershed boundaries (mountain axes) and valley axes. In order to obtain this measure I calculate the shortest path distance to valley axes ($P_S$) and watershed boundaries ($P_M$). I then relate the two measures in order to obtain a relative measure of valley position ($P_V$). Values of $P_V$ close to 1 correspond to locations close to watershed boundaries while values close to 0 correspond to locations close to valley axes:

$$P_V = \frac{P_S}{(P_S + P_M)}$$

There are some problems with this measure as watershed boundaries near major valley intersections, for example where the Avra Valley watershed meets the Upper Santa Cruz Watershed, do not correspond to mountain axes and may be physically very close to valley axes. In a general sense, however, we can consider this measure to correspond to surfaces that are more likely to be erosional or stable (watershed boundaries) and surfaces that are aggrading (closer to zero). A better measure may be obtained by allowing watershed boundaries to occur only along the axes of topographical prominences (i.e., mountain chains and hill summits).
Figure 9.1 The cumulative frequency distribution of site area with respect to watershed position. Values close to one denote location close to watershed boundaries, values close to zero denote locations close to valley axes. From bottom to top – AZSITE site areas, IFNM sample areas, IFNM site areas. Around 70% of total site area occurs in upland zones despite the fact that only upland zones comprise only around 30% of sampled areas.

As a first approximation, the distribution of site area with respect to watershed position reveals an interesting trend. About twice as much site area as IFNM sample area occurs in upland, watershed boundary positions (Figure 9.1). Though not represented in Figure 9.1, the distributions of values for the entire IFNM landscape (sampled and
unsampled areas) are not significantly different than distributions of values for the IFNM samples. Differences between the sample unit distributions and site area distributions are highly significant (chi square = 20.3, df = 3, p = 0.001), indicating that site area does tend to be greatest in upland settings. Most of these are upper bajada settings. The pattern of site positions within watershed is interesting when contrasted to sites in adjacent areas of the Avra Valley, Northern Tucson Basin, and Lower Santa Cruz valley recorded in AZSITE. Sites in these areas, compiled from many different surveys over several decades, tend to be more evenly distributed with respect to valley position. The smallest amount of site area for sites in AZSITE occurs at positions farther from the valley axes. The problem with the measure outlined above would only accentuate this difference, as sites near major valley intersection (values ranging between zero in one) are most accurately described as close to valley axes. The opposite trend is observed in the IFNM archaeological landscape.

One major difference between the two data sets may simply be a strong tendency for most cultural resource inventory projects (and hence most recorded sites) to occur in areas proximate to valley bottoms. The smaller contributions of sites in the upland areas in the AZSITE data may simply pertain to less survey coverage in these geographic settings (cf. Schiffer and Wells 1982). In the IFNM, large contributions to total site area in upland locations close to watershed boundaries suggest that there may be a greater chance for larger sites to be observed in these areas because of less exposure to artifact redistributing and burial processes. In other words, more site area in upper bajada
settings of the IFNM may signify greater surface visibility of archaeological landscape elements rather than more intensive use of these settings.

On the other hand, it could be that the relatively low-lying mountain and bajada settings of the IFNM have tended to be the zones most often targeted for use. These areas contain relatively abundant cactus and tree species that would have been valuable to both prehistoric and historic people for fruits, beans, seeds, and wood. A number of sites in upper bajada settings may represent historic cactus camps, while others are dense palimpsests of ceramics, ground stone, and flaked stone tools from diverse time periods. The upland settings of the IFNM currently host small populations of desert bighorn sheep, mountain lion, and mule deer. The upland zones were likely exploited as hunting territories, as suggested by concentrated zones of projectile point finds and petrolglyphs of game animals, such as desert bighorn sheep). In the Sawtooth Mountains, rock shelters in the mountain foothills were likely used for diverse activities over long time periods. Historic mining activities also exploited resources found in these zones — ore body and wood. Many topographic prominences in the IFNM also afford excellent views of major valley systems. Thus, plant gathering, hunting, landscape monitoring, mining exploration and exploitation were some prehistoric and historic activities that tended to focus on upland resources.

However, we know that the Kohatk occupied fairly extensive residential villages for part of the year near the Santa Ana visita in the Aguirre Valley (Dobyns 1974; Fontana 1987; Hackenberg 1974). Evidence for historic indigenous occupation of the area is observed, but at fairly low densities. Likewise, residential and agricultural
activities are indicated by archaeological excavations in lower portions of the Avra Valley (Dart and DeMaagd 1994). We might assume that equal rates of artifact deposition and feature construction probably transform differently in upland versus lowland settings. Upland archaeological concentrations may be subject to fewer or less intense burial processes and less surface turnover (through bioturbation, agricultural practices, or modern disturbances) and thus tend to remain more continuously visible at the surface. Lowland archaeological concentrations may be subject to more frequent and more intense burial processes such as alluviation and surface turnover (i.e., bioturbation in finer, loose sediments, creosote mounding), resulting in more fragmented, less visible artifact and feature concentrations. Thus, we might hypothesize that the large amount of site area in upland settings of the IFNM results from broad–scale landscape formation processes differentially affecting the surface distribution of archaeological materials.

Power Laws, Site Area, and Artifact Density

As stated above, two very basic dimensions of archaeological landscapes are site area and artifact density and these variables may be related through fractal growth processes. In the IFNM survey, onsite artifact density was measured according to standardized, randomly placed 1 x 1 m and 2 x 2 m quadrats. Sites were discovered and recorded with respect to 800 x 800 meter quadrats and 80 m wide transects of variable length.

Fine–scale variation in artifact density and more broadly scaled variation in site size may correspond to different levels of artifact clustering. In this sense, we might
consider a survey sample as similar in some ways to a density plot. Thus, we might consider the total amount of site area intersected by a sample as broadly comparable to the number of artifacts intersected by much smaller density plots.

The total amount of site area intersected by a sample plot divided by sample plot area produces a power law distribution for both transects and quadrats (Figure 9.2). Artifact densities also follow a power law distribution (Figure 9.3). The exponents for these relationships are similar (~2.2) suggesting that artifact distributions and site sizes have scale–invariant properties that are potentially related to fractal growth processes.

As site area doubles the frequency of this occurrence decreases by 2.8. Similarly, as artifact density doubles, the frequency of this occurrence decreases at a similar rate. This possible power law distribution results from sampled, site distributions that aggregate all observed prehistoric and historic time periods (including a variety of broadly defined culture periods: Late Archaic, Hohokam, Protohistoric, Indigenous and EuroAmerican early to late Historic), all feature and artifact types associated with sites, and all environmental site contexts. It seems unlikely, then, that this distribution is causally related to the properties of one or more systemic landscapes. While I do not argue that behavior or people–material interactions do not play a role in site–size distributions or artifact densities, this distribution emerges despite almost all assumptions about the underlying causes of archaeological site distributions.
Figure 9.2  The power law relationship between site area and frequency: $F_a = 0.005495 / A_s^{2.26}$, where $F_a$ = relative frequency and $A_s$ = site area divided by sampled area.

Although there are many potential explanations for this phenomenon, the distribution may identify a basic property of the surface archaeological landscape. This power law distribution suggests that the IFNM archaeological landscape does contain large clumps of archaeological sites (~4%), but most of the archaeological landscape is composed of fairly dispersed, small archaeological sites and isolated finds. This highlights the point that the larger proportions of archaeological landscapes are defined not by huge concentrations separated by archaeologically empty space, but by broadly,
Figure 9.3 The power law relationship of estimated site artifact density ($D_a = \frac{\text{artifacts}}{100 \text{ m}^2}$) to frequency ($F_a$). The relationship, $F_a = 10^{7.27}/D_a^{2.13}$ ($r^2 = 0.992$, $p < 0.001$), has a $\lambda$ value (2.13) similar to that for the proportional site area – frequency relationship above ($\lambda = 2.26$).

dispersed artifacts and features often ignored both analytically and methodologically. This property of archaeological landscapes is a significant management concern.

This relationship appears to apply equally to both linear transects and quadrats, even though the two sample unit geometries can vary considerably in both shape and size. Transects were on average 1.7 times smaller than quadrats in area and 6 times longer than quadrats in maximum dimension. Nonetheless, both sample types yielded
Figure 9.4 Size frequency relationship for 2102 archaeological sites recorded in the Northern Tucson Basin. The relationship \( F = 5.61 \times 10^{10} / A_s^{1.79} \) has a “fat tail.” Finding the relationship for a limited range (up to 420,000 sq meters) yields an exponent similar to that found for IFNM samples \( \lambda = 2.1 \).

similar frequency distributions for site area, suggesting that an identical relationship occurs independently of sample unit type.

A similar relationship obtains for 2,102 sites recorded in areas adjacent to and within the IFNM (including portions of Santa Cruz Flats, Northern Tucson Basin, Avra Valley, Aguirre Valley, and Santa Rosa Valley) (Figure 9.4). The relationship obtains despite the fact that these sites (which include the IFNM sample) were recorded during different time periods, according to a wide variety of methodologies, and by many
different researchers. Survey techniques may certainly play a role in either distribution, but the exponent obtained (by one method) for larger site sizes (see next section) is similar to that obtained for IFNM samples ($\lambda \sim 2.1$).

These relationships occur despite the many details of archaeological deposits. Despite variation in artifact types, site types, environmental settings, visibility, depositional context, or sample unit size and shape, we obtain similar scaling factors (with different empirically derived constants). The implication is that archaeological landscape patterns have similar properties at widely different scales.

One implication of these relationships is that site formation, like many ecological processes, produces fractal patterns. Despite broad variations in sample unit size (128,000 m$^2$ to 640,000 m$^2$ for IFNM survey sample units; 1 m$^2$ to 4 m$^2$ for density plots) and measurement techniques (visually estimated site area versus observed artifacts per random density plot), both relationships scale in a similar manner. As ontogenetically related phenomena, patterns in archaeological phenomena may carry over across scales.

Another implication is that, as already anticipated by site formation theory, systemic behaviors are only one of many inputs influencing the density of archaeological occurrences (artifact and site densities). Randomly sampling archaeological sites for artifact densities and randomly sampling archaeological landscapes for site densities yield similarly scaled results. As these relationships are obtained despite their derivation from numerous behavioral systems operating over the course of at least several thousand years, the fractal dimension of archaeological landscape densities likely pertains to complex
networks of processes that link both human activities, ecological, and geophysical processes across a wide variety of spatial and temporal scales.

Methods For Investigating Power Law Distributions

Archaeologists often treat dimensions of interest, such as size or duration, as if they were normally distributed. While some kinds of metrics fall into a Gaussian distribution, many do not. We thus resort to statistical tests that do not assume normal distributions. These allow investigations of archaeological dimensions that do not meet requirements of normal distributions.

A serious problem with estimating power law relationship from frequency distributions is that different methods yield different results. In this study, I do not aim to find the most accurate estimates of scaling exponents for investigated power law relationships. Rather, I am interested in demonstrating that power law scaling does occur for archaeological and systemic landscape dimensions and to explore the implications of these relationships.

It is important to recognize, however, that scaling exponents can vary according to how they are obtained as well as by the phenomena they are used to investigate. For this section I examine variation in power law relationships with respect to power law fitting methods and sampling issues. By way of illustration, I do this by re-examining the size–frequency relationship obtained above for AZSITE and IFNM site areas.

Typically, investigators identify power laws by looking for a linear fit between two variables on log–log plots. This linear relationship is considered to be the
characteristic graphical signature of power laws. In order to estimate the relationship (and thus obtain the scaling exponent), investigators use at least five estimation methods: 1) least squares regressions (LSRs) of linear binned data; 2) LSRs of the first five points of linear binned data; 3) LSRs of logarithmically binned data; 4) LSRs of ranked data; and 5) Maximum Likelihood Estimation (MLE).

MLE approaches have recently been argued to yield the most robust estimates of scaling exponents (Goldstein et al. 2004). Since the MLE method involves solving a complex, differential equation to obtain the scaling exponent, it is probably beyond the mathematical comfort zone of most archaeologists. Archaeologists interested in obtaining the most accurate, least biased estimate can use software platforms such as Matlab to obtain the desired result. I instead compare site area – frequency distributions using the other methods listed above.

One problem with the site area data obtained from AZSITE is that a large number of very small site sizes (size $\leq 100 \text{ m}^2$) appear to result from site point data being conservatively translated into polygon data. In other words, recorded sites that have no reliably recorded site size or shape and are only reported as points are entered in AZSITE GIS as 5 m x 5 m or 10 m x 10 m polygons. As a result, these site polygons (which do not represent field estimates of site size or shape) bias the distribution towards smaller size classes. Removing these cases has significant effects upon the estimated power law relationship (Figure 9.5)
Figure 9.5 Frequency–size relationship for linearly binned AZSITE and IFNM site sizes (bin width = 20,000 m²). The open triangles represent the smallest size bin for different minimum sizes (> 0, 25, 100, 900, 1850, 2500, 3400, 3900 from top to bottom). The estimated relationship is based on the first five data points, using a minimum site size of 3900 (the trimmed median): \( F_s = 10^{11.513} / A_s^{2.038} \).

Biases in the data lead to overestimation of the frequency for the smallest size class. Consequently, the scaling exponent is also overestimated (as the slope of the line on a log–log plot is equivalent to the scaling exponent). Adjusting the minimum size value in response to this bias has the effect of reducing the scaling exponent and increasing the significance of the relationship (Table 5.1).
<table>
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<td>&gt; 900</td>
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<td>2.70 x 10^{14}</td>
<td>6.97 x 10^{13}</td>
<td>1.13 x 10^{13}</td>
<td>3.30 x 10^{12}</td>
<td>6.95 x 10^{11}</td>
</tr>
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Table 9.1  Values for 8 power law relations obtained for site size – frequency relationship when minimum site size (a) is allowed to vary. Each relationship follows the form \( F_s = \frac{K}{A_s^\lambda} \).

The values in Table 9.1 show that the scaling exponent of the site size–frequency relationship varies from 2.8 to 2.0, depending on the minimum site size included in the calculation. Graphical examinations of relations 1 through 4 reveal a relatively poor fit, given the influence of the smallest size bin. The most reliable estimate for \( \lambda \) is probably between 2.2 to 2.0, corresponding to a minimum site size of 2500 to 3900 m².

As can be observed in Figure 9.5, fat tails are characteristic of linearly binned power law relationships. This stochastic variation results in underestimated \( \lambda \) when a large number of bins are used to estimate the relationship. When all bins, rather than the first five, are used to estimate the site size – frequency relationship, we obtain a much less reliable estimate with a considerably lower scaling factor (\( F_s = 1.66 \times 10^9 / A_s^{1.572} \)).
Logarithmic Binning Method

One way to smooth out the fat tail in power laws is to logarithmically bin site sizes. On a log–log scale, logarithmic bins appear evenly spaced. Logarithmic bin sizes (Δ) can be obtained by the following relationship (Wuchty 2004):

\[ \Delta = \frac{1}{N} \log \left( \frac{b}{a} \right), \]

where \( N \) is the number of bins, \( b \) is the maximum site size and \( a \) is the minimum site size.

The bin membership (\( n_i \)) for the \( i \)th site can be determined by the formula:

\[ n_i = \frac{\log (A_i / a)}{\Delta}, \]

where \( A_i \) is the \( i \)th site area.

Figure 9.6 shows the logarithmically binned frequency–site area relationship for \( a > 100 \). While noise in the tail of the relationship has been reduced, the slope of the relationship (\( \lambda = 0.625 \)) is far below that obtained for the linearly binned relationship. This is partly because a “logarithmically binned noncumulative distribution is equivalent to a cumulative distribution” (Turcotte et al. 2002). The scaling exponents of noncumulative power law distributions and cumulative power law distributions (\( \lambda_a \) and \( \lambda_b \), respectively) are related, such that when \( \lambda_a > 1 \), \( \lambda_b = \lambda_a - 1 \). The scaling exponent obtained for the logarithmically binned site size–frequency relationship thus corresponds to a linearly binned estimate of 1.625. This value is still considerably below that obtained through the linear bin method, but underestimation appears to be characteristic.
Figure 9.6 Frequency – site size relationship with logarithmically binned data. The solid line is the power law relationship \( F_s = 10^{4.837} / A_s^{0.625} \) for points above the median (dashed line).

of the logarithmic binning method. A Monte Carlo sampling experiment, performed on a power law distribution with a scaling exponent of 2.5 yielded similar results to that obtained here for the different methods for estimating the site area – frequency relationship (Goldstein et al. 2004). While MLE performed best in that experiment, linearly binned 5 points estimation produced very similar results.

Logarithmic binning reveals an interesting property of the site size – frequency distribution that is not apparent in the linear binning method. When logarithmically
binned, the distribution is still extremely right skewed, but shows a distinct mode. The mode of the relationship also happens to converge on the median (Figure 9.6). Though the relationship still could be argued to have a power law tail, there is a typical range of site sizes that tend to get assigned.

The appearance of a mode suggests that below a certain value, smaller and smaller site sizes become less frequent (and thus there may be a minimum site size). The logarithmically binned site size distribution exhibits linearity in both upper and lower tails and because of this may be what is referred to as a double Pareto log normal distribution (DPLN). A DPLN distribution is generated by processes following geometric Brownian motion (a random walk procedure). Reed’s (2001, 2002) mathematical model for the generation of DPLN assumes that at a global (or macro) level, time–transgressive growth processes (such as the growth of human settlements) involve so many complex interactions as to be essentially random (Reed 2001, 2002).

In the DPLN model, settlements (or in our case archaeological sites) emerge at different times and according to variable initial conditions. The size of established settlements changes over time following a log normal random variable. In order to allow for historical growth processes, new settlements emerge according to a Yule process, which expects that the number of settlements after initial colonization is $e^{\lambda t}$, where $\lambda$ is a proportional growth rate and $t$ is time. The distribution of site sizes observed at any point in time (i.e. an archaeological survey) produces a DPLN. This distribution results from a combination of random log normal distributions and produces a power law upper tail and a reverse power law lower tail (Reed 2001, 2002).
Although missed in many empirical examinations of Zipf’s Law, the reverse power law lower tail predicted by the DPLN model actually does occur in human settlement distributions. Like site sizes above, Zipf’s law for city size distributions may only hold above a critical threshold size. Power law behavior in city size distributions can be simulated by simple random walk behavior (Reed 2001, 2002).

An alternative explanation for the shape of the logarithmically binned site size distribution is that methodological research bias prevents researchers from designating sites below a certain size. Small, artifact and feature concentrations otherwise meeting site definition requirements are dismissed as “isolates” or missed by wide sampling intervals. As a result, the probability of intersecting and identifying a site increases with site size until a critical size is reached. I revisit this possibility below.

*Rank–Size Distributions*

Still another way to investigate power law distributed data is through rank size distributions. Rank size power law distributions are classic examples of Zipf’s Law. The exponent for rank size distributions of cities frequently approaches unity. Analysis of rank size distributions often entails assumptions of system hierarchy, as the largest cities are thought to correspond to the highest levels of organization. Rank size distributions are also often concave to the origin, having power law scaling only over segments of the
Figure 9.7 Rank size distribution of 25,000 words from English Internet Corpus, a corpus of 110 million English words used on the internet (author’s analysis of data from http://corpus.leeds.ac.uk/list.html). Count is word frequency per million words.

distribution. Many different explanations have been posed for power law scaling in rank size distributions of cities.

As observed by Zipf (1949), word frequencies also exhibit power law scaling. In Figure 9.7, a rank size distribution for 25,000 English words I analyzed is shown. The words are derived from a corpus of English words used on the internet and available at the internet site http://corpus.leeds.ac.uk/list.html. Remarkably, just 5.8% of 25,000
words accounts for 55% of word uses. My analysis shows that the relationship is roughly linear on a log–log plot, but slightly concave toward the origin. A change in the slope of the relationship occurs at a rank of ~ 1450. This change in slope on the log–log plot corresponds to a shift in scaling exponents (from ~0.9 to ~ 1.4), that may signal scale shift in a broad order of word choices.

The highest ranked words (i.e. 1 = “the,” 2 = “of,” 3 = “and,” 4 = “to”) probably serve to connect a lot of other words in networks of words. Changes in the slope of the relationship signal shifts in how word use scales to word rank. One could interpret the entire distribution in terms of a single relationship or two or more relationships. Estimating the relationship for the entire distribution yields a scaling exponent of ~ 1.24. A large number of highly ranked outliers, however, suggest that the slope is increasing with rank ($r^2 = 0.985, P < 0.001$), as the concavity of the distribution indicates. Dividing the distribution into two segments, yields much closer fits to the data.

I am not alone in interpreting this relationship as consisting of two scaling regimes. In a study of the British National Corpus, Cancho and Solé (2001) found two power law scaling regimes. They hypothesize that the two regimes correspond to a kernel lexicon comprising the core of words for basic communication and a specific lexicon of less frequently used words that are shared only by some members of a lexical community. They argue that the area of the distribution where the scaling regime shifts corresponds to the size of the kernel lexicon. For the British National Corpus, this shift occurs on the order of 5,000 to 6,000 words. For pidgin languages, this shift may occur at a rank of ~ 1,500. The scaling exponents and scaling regimes obtained by Tuldava
Figure 9.8 Rank size distribution of for site sizes (m²). Site sizes from AZSITE database.

(1996) for the A. H. Tammsaare’s novel *Truth and Justice* are similar to those I obtained for the English Internet corpus above, suggesting that kernel lexicon for internet communication is small compared to the British National Corpus but similar in size to those of pidgin languages.

*Scaling Regimes in the Rank Site–Size Distribution*

When sites are ranked according to size (rank = 1 for largest site), only segments of the rank – size relationship exhibit power law scaling (Figure 9.8). Close examination
Figure 9.9 Rank–size distributions for Archaic, Ceramic, and Historic period sites in AZSITE.

of Figure 9.8 reveals four possible linear segments, each of which can be described by a different power law relationship or scaling regime. The first two segments have exponents similar to those obtained for words above. Unlike rank size distributions for cities and words, the distribution for sites inflects strongly within the range of site ranks 1250 to 1800 (between 255 m$^2$ and 2300 m$^2$). As suggested by the logarithmically binned distribution above, site size diminishes at an increasing rate below a critical threshold.
Breaking up this distribution into broad temporal periods (Figure 9.9) suggests that the aggregated rank–size distribution is largely the result of Ceramic period sites. Interpretation of these distributions is complicated by the fact that most Archaic and Historic sites have Ceramic period components. Scaling exponents and general form for the Ceramic period distribution are similar to the aggregated rank–size relationship. Historic period and Archaic period distributions are generally steeper, but this is largely because there are fewer Archaic and Historic sites. Without re-scaling the X axis, Archaic and Historic sites occur over a similar size range as Ceramic sites, but are distributed over a smaller range of site ranks, resulting in steeper slopes. The inflection points are the same for each period, so the inflection very likely results from methodological bias against recording small sites.

If we consider the “rich–get–richer” effect (Bentley 2003b; Newman 2000, 2003) and the Arlo Guthrie trash magnet effect (Schiffer 1987; Wilk and Schiffer 1979), it may be the case that existing places in systemic landscapes that are used earlier have a greater tendency to invite reuse. Places that possess some advantage earlier on may get reused at a greater rate than other places. Just as wealth attracts more wealth and trash attracts more trash, place use may attract more place use. Existing places may have artifacts and facilities that can be reclaimed or recycled and their previous use may also enhance their accessibility (i.e., trail systems, clearings). Places used during Archaic time periods may have had a tendency to be reused more often, resulting sites that grow at a faster rate than others. Similarly, Historic period people may have preferentially used previously used places, increasing their growth rate.
Figure 9.10 Rank–size distributions for Archaic, Ceramic, and Historic period sites in AZSITE with X axis re–scaled.

When we re–scale the Historic and Archaic rank size distributions to match the maximum rank for Ceramic sites, Historic sites are distributed similarly to Ceramic sites. Archaic sites, on the other hand, are consistently larger. The tendency for Archaic sites to be consistently larger than Historic and Ceramic sites of comparable rank may be a problem of site recognition. Lack of ceramics and historic materials at purely Archaic sites makes them more difficult to diagnose temporally. Ceramic sherds and historic materials are far more numerous than projectile points making such materials more likely to be observed in archaeological context. The larger a site becomes, the larger the
potential sample of artifacts to be observed. Archaic diagnostics, such as projectile points, may have a greater likelihood of being observed at large sites rather than small sites because the sample of observed artifacts is sufficiently large.

Discussion

How important archaeological landscape dimensions vary with changes in scale (as well as vary with each other) should be important components of archaeological landscape investigations. If we want to investigate and understand broad-scale constructs such as landscapes, we must identify and explain variation in patterns across a broad range of scales. Also, we must identify how other landscape dimensions or methodological biases affect dimensions of interest.

Archaeologists are often concerned with how archaeological dimensions, such as site size, vary with environmental context. Topography and proximity to basic resources, such as water, are often considered to be variables that strongly influence or control the density or occurrence of archaeological manifestations. Although topography and proximity to basic resources may certainly affect behavior, we cannot assume that spatial distributions of archaeological manifestations directly reflect spatial distributions of behaviors.

As an example, I examined the relationship between site area and valley position. I constructed a relative measure (PDVREL) that describes the relative position of a 30 x 30 meter grid cell within a hydrological unit or valley. All grid cells containing sites were given a value between zero and one, describing whether it was relatively close to
valley axes, as defined by major washes, or close to upland settings. I compared the valley position of IFNM sites, AZSITEs in areas close the IFNM, and IFNM sample units using cumulative distributions of this measure.

It turns out that over 60% of site areas within the IFNM occur in upland areas, whereas almost the opposite trend occurs for sites recorded in AZSITE. This trend may result from the tendency of many archaeological survey projects to occur where most development occurs — in lowland areas close to population centers (Schiffer and Wells 1982). A major implication of these results is that significant portions of archaeological landscapes may be strongly underrepresented in existing data sets and that analysis of archaeological manifestations with respect to basic environmental contexts may suffer from severe methodological biases in the recordation of sites.

In a previous chapter, I argued that investigating properties of archaeological landscapes at a variety of scales may reveal patterns that are scale–invariant, or similar across a broad range of scales. I used two basic dimensions of archaeological landscapes to explore this possibility: artifact density and site size. Both dimensions can be described according to power law statistics. Since the exponents for IFNM artifact densities, IFNM site size, and AZSITE site size power law relationships are similar, I offered the working hypothesis that fractal growth processes may be responsible for the similarity in these distributions (Brown 2001; Brown and Witschey 2003; Brown et al. 2005).

Methods for investigating scaling relations affect results. I thus explored site size distributions according to a variety of different methods: 1) least squares regressions
(LSRs) of linear binned data; 2) LSRs of the first five points of linear binned data; 3) LSRs of logarithmically binned data; and 4) LSRs of ranked data. LSRs of linear binned data are affected by the “fat tails” characteristic of power laws. LSRs of all data points for the entire distribution thus yield inaccurate results. LSRs of the first five points of linear binned data, on the other hand, ignore the fat tails and give results that describe the distribution reasonably well (Goldstein et al. 2004). The site size distribution was described best by LSRs that discarded sites below a threshold site size. Some of this problem relates to how sites with no reliable size or shape information are recorded in AZSITE, but clearly other methodological factors, such as recordation bias, play a role.

Turning to LSRs of logarithmically binned data, I found that the site size distribution is distinctly modal and that this mode appears to align with the threshold site size discussed above. The site size distribution may in fact be a double Pareto log normal distribution (Reed 2001, 2002) that is describable by a power law relation with a positive exponent for small site sizes and a negative exponent for larger site sizes. In other words, at the lower end of the site size distribution, the probability of a site being recorded actually increases with site size.

If we were to describe this phenomenon in behavioral terms, it is possible that sites need to be a minimum size to accommodate fine–scale activities typically performed by one or a few individuals. In other words, sites may tend to be a modal size because of behavioral factors that impose constraints on how small — and possibly how large — a site can be (Fletcher 1995). On the other hand, small sites may be recognized far less often than they actually occur, making small sites less likely to be recorded. The mode
observed in the logarithmically binned distribution, that also likely affects LSRs of the linear binned distribution, may be an artifact of methodology, rather than a consequence of spatial constraints on human behavior.

Finally, I examined rank size distributions (Zipf 1949). The rank size distribution for site size shows a strong inflection point near the same size threshold as indicated by the other methods. When this distribution is separated out into Archaic, Ceramic, and Historic period distributions, all three distributions continue to inflect at the same point. We might expect that variation in spatial requirements of activities between the three periods would result in variation in the inflection point of the rank size distribution. The fact that the inflection point does not vary between the distributions suggests that the relative scarcity of small sites, regardless of period, results from methodological bias and not from some innate property of human behavior.

A general lesson to be learned from these exercises is that investigation of potential scaling relations in archaeological landscape dimensions benefits from the application of multiple parallel analytical methods. Using only a single analytical technique may mask important variation or make it difficult to understand why unexpected deviations occur. Using multiple methods helps expose important deviations and irregularities that might otherwise be ignored or misunderstood. Site size and artifact density are describable according to power law statistics and this fact may have important implications for how basic archaeological dimensions tend to be distributed as well as how they relate to each other. The data, however, are imperfect. We must caution ourselves that the exact influence of methodological bias and behavioral variation on
archaeological landscape dimensions may be difficult to determine until methods for observing and recording archaeological landscape dimensions are further refined.
CHAPTER X — DISCUSSION AND CONCLUSIONS

In this study I have built a theoretical framework for landscape archaeology. In doing so, I addressed fundamental questions. Where do concepts in landscape archaeology come from? How does the development of landscape archaeology fit into the history of anthropology? What kinds of landscape archaeology are being practiced today and what are their basic assumptions?

As landscape concepts and methods are becoming important in related environmental disciplines, I investigated the role of landscape in geography and ecology. In geography, I pointed to Sauer’s early conceptualization of geographical landscapes. In ecology, I pointed to some conceptual and methodological tools and common goals shared between landscape archaeology and contemporary landscape ecology. I compared gradient analysis and patch analysis and found parallel issues between landscape archaeology and landscape ecology in addressing problems of scale and units of analysis.

Addressing the critical concept of scale, I examined scale issues along temporal, spatial, and social dimensions. I considered how issues of scale relate to the description and interpretation of archaeological and systemic landscapes. How do we identify the scale of archaeological patterns and systemic processes? How do the scales of archaeological patterns relate to scales of systemic processes? Are they scaled to each other? How do we define something as basic as the size of a landscape?

In discussing scale, I introduced the concept of landscape allometry. I identified different kinds of biological and ecological allometric relationships and discussed how
they have been interpreted. I advanced the conjecture that similarly scaled relationships may also exist in archaeological and systemic landscapes. I showed that relationships between residential mobility and population density are allometric and may be explained as properties of systemic landscape networks. Since power law relationships are potentially linked to fractal dimensions I suggested the potential use of scaling relations to predict broad-scale patterns from fine-scale data.

Turning to the conceptualization of landscapes in archaeology, I addressed basic ways of modeling landscape interactions. I argued that emic or systemic perception of landscapes is intimately related to the utility and functionality of emically defined landscape elements. Rather than environment or culture determining human–environment interactions, I argued that the interaction of cultural logic and practical reason (Sahlins 1976) guides systemic landscape formation. In advancing this argument, I discussed how strategic landscape behavior and landscape perception are related. Further, I looked to encounters with unfamiliar landscapes as examples of the interactions of founding sets of techno–ecological strategies with novel characteristics of colonized landscapes. I examined evolutionary ecological models of habitat perception and selection and discussed the notion of taskscape, or “a pattern of activities ‘collapsed’ into an array of features” (Ingold 1993:162,) as it corresponds to differential performance of activities across evolving landscapes.

Having addressed some basic issues such as where landscape archaeology comes from, areas of inquiry, and scientific goals, I advanced the notion of landscapes as networks. I suggested that landscapes can be modeled according to network topologies.
Places are network nodes and routes are network links. After examining some basic kinds of networks and their implications for the structure and properties of landscape networks, I built a network model of human–environment interactions.

Issues of scale and network topology converge in the discussion of landscape hierarchy. I argued that spatio–temporal landscape processes can be regarded as hierarchically structured, such that higher level processes constrain lower level processes. I suggested that while environment does not determine behavior, landscape configuration constrains and enables the kinds of interactions likely to occur. As an example, I compared basic environmental characteristics of Sonoran Desert and Australasian landscapes and suggested that differences between the two areas may partially explain why agriculture developed in the American Southwest but never emerged in Australia despite at least 40 kyrs of human occupation. I presented the Bintliff and Snodgrass (1988) model for offsite ceramic distributions as another example of landscape hierarchy, where broad–scale variation in climate and erosion constrain basic properties of archaeological landscapes.

In chapter eight, I turned to systemic landscapes of Ironwood Forest National Monument (IFNM). I presented several different models of systemic landscapes based on ethnographic, historic, and modern data: 1) Akimel O’odham landscapes; 2) Tohono O’odham landscapes; 3) Kohatk landscapes; 4) Historical Mining and Ranching landscapes. I discussed how each of these kinds of landscapes is a network, and how changes in network topology effectively mean changes in landscape interaction. I discussed some characterizations of prehistoric landscapes, particularly Hohokam
landscapes, and identified some problem issues in the interpretation of systemic landscapes from archaeological patterns.

I then turned to the properties of archaeological landscapes. I examined the global properties of archaeological landscapes along several basic dimensions. In investigating the possible occurrence of power laws in archaeological data, I compared methods for estimating power law relationships and weigh interpretations of power law relationships for other kinds of phenomena. I conceptualized archaeological landscapes as hierarchical networks of behavioral, ecological, and environmental processes. I suggested that, just as one can build models that place the ultimate cause of archaeological patterns in systemic behavioral patterns, there may be some natural laws of archaeological matter.

One of the primary strategies of behavioral archaeology is the search for behavioral regularities. Some investigators have claimed that the search for laws of human behavior is considered possible only in situations that are so general that they are trivial and essentially meaningless (O'Brien and Holland 1995). Archaeological practice, whether explicitly behavioral or otherwise, is rife with both low and high-level principles, and these are general only in terms of their respective levels of comprehensiveness and empirical content (Schiffer 1988).

In any early paper, Schiffer (1972) addresses an apparently simple question: Why is there an archaeological record? Following Binford and Binford (1968), Schiffer (1972:156) advocates “explaining how the archaeological record is produced in terms of explicit models, theories, and laws of how cultural systems operate.” Schiffer presents a
A general model for the life-history of artifacts that continues to be valuable today. The life-history of durable elements can be modeled in terms of five interacting processes: procurement, manufacture, use, maintenance, and discard. The life-history of consumable elements is modeled in terms of analogous processes: procurement, preparation, consumption, and discard. Processes of reuse, recycling, and lateral cycling further differentiate the life-histories of systemic elements. A crucial concept in his model is use-life. Differential use-lives of artifacts result in differential discard rates and help to explain the proportionality of archaeological elements in spatio-temporal contexts. When use-life is expended, systemic elements enter archaeological contexts as refuse. In this model, there is an archaeological record because systemic elements have differential life histories, histories that end in loss or discard at variable rates and in accordance with variable activities. While Schiffer (e.g., 1987) certainly accounts for the distorting effects of natural formation processes on archaeological deposits, his early model argues that people-material interactions are the ultimate source of spatio-temporal variation in the archaeological record (see especially, Schiffer and Skibo 1987; Shott 1989, 1996; Surovell 2003; Varien and Mills 1997; Varien and Ortman 2005).

From this model, Schiffer (1972) is able to derive a number of principles of the spatio-temporal dynamics of people-artifact interactions. He convincingly argues the implications of his model – the spatial location of archaeological occurrences does not directly reflect where artifacts were used in systemic contexts. Further, archaeological occurrences are not spatially random with respect to behavior. The organization of artifacts in time and space, then, is neither homologous to spatio-temporal variation in
artifact use, nor entirely random. The utility of this model resides in the fact that it
privileges people–artifact interactions as a uniquely archaeological domain of inquiry and
explanation.

While I agree that archaeologists should focus on building uniquely
archaeological models and investigative frameworks, we do not do so in a vacuum. Like
other disciplines, we are products of our times. We should be aware of scientific
advances in other disciplines. And we knowingly and unknowingly borrow concepts and
methods from other disciplines on a routine basis. Behavioral models, as Schiffer has
built and tested, are of special value to archaeology. However, the program of behavioral
archaeology involves so many potential contexts and forms of people–material
interactions that a diversity of theories is necessary.

Indeed, Schiffer and Miller’s (1999) recent theory of communication argues that
humans are practically swimming in artifacts that participate in performances on all
levels of human experience: perception, communication, interpretation, in addition to
more traditionally studied behaviors. Human behaviors are performed within a universe
of interacting matter and energy. In the course of everyday lives, humans take part in
innumerable energetic and material interactions across a wide range of spatio–temporal
scales of activity.

Because of this deep human participation in the broad range of living and non–
living systems, human material and energetic interactions may be subject to deep
organizing principles. There are certainly behaviors that result in distinct archaeological
consequences. There may also be nomothetic, statistical laws of archaeological matter
that transcend the details of particular behaviors, meanings, and contexts. Archaeological materials, and by extension archaeological landscapes, may be partly organized by natural laws of archaeological matter. These laws may relate to the emergent properties of complex systems, such as archaeological landscapes, and hence regulate the formation of basic characteristics of archaeological patterns. While I have explored the emergence of power law scaling in some basic components of archaeological and systemic landscapes, this only scratches the surface. In order to recognize other meaningful and potentially pervasive relationships, archaeologists will need to develop novel forms of quantification that are appropriate to archaeological materials and contexts. The new quantification might allow us to explore the topology of landscapes as networks by modeling the flow of matter, energy, and information through landscape networks.

Archaeological and Systemic Context Revisited

I have emphasized that, from an archaeological perspective, there are two basic types of landscapes: archaeological landscapes and systemic landscapes. Systemic landscapes are generally the kinds of landscapes archaeologists are interested in exploring. Much landscape literature explores the properties of landscapes as they are lived. Other approaches deal more explicitly with the properties of archaeological landscapes, and explore how these observed properties can be used to make inferences about the nature of systemic landscapes. In many cases, however, archaeological landscapes are conflated with systemic landscapes. Investigators simplistically interpret observations on archaeological landscapes as observations on systemic landscapes.
From a behavioral standpoint, we need to explore how the local interactions of people and materials form larger systems of landscape–level phenomena. In other words, we need to understand how common forms of behavioral interactions (i.e., thermal, acoustic, physical, chemical) relate to each other to create broad–scale landscape patterns. Artifact life–histories are a potentially productive starting point for building simulation models of landscape formation. It may be necessary, however, to reconfigure directional or looping behavioral chains as behavioral networks (e.g., Gariaschelli et al. 2003; Pahl-Wostl 1997) that can account for the potential complexity of people–material interactions and their broad, diffuse relationships across vast arrays of activities. Like food webs, behavioral networks may have topologies somewhere in between less efficient chain–like, sequential feeding relationships and highly efficient, star–like network topologies where species have more closely connected relationships with environmental resources (Gariaschelli et al. 2003).

In this study, I have opined the lack of a general theoretical framework for landscape archaeology. Rather than a review of existing approaches or a highly focused study on one or two dimensions of archaeological landscapes, I have attempted to address the lack of theoretical foundations in landscape archaeology. I have attempted to build a general theoretical framework upon which future studies can be based. This study is thus a kind of extended prolegomena or scientific manifesto intended to guide the work that I — and hopefully others — will undertake in the future.

Complex systems and their emergent properties that now fill the pages of scientific journals participate in the formation of landscape systems. The task now is to
develop new ways to measure the properties of archaeological landscapes and new ways to model systemic landscape interactions so that we can begin to formulate middle range theory of how archaeological landscape patterns emerge from systemic landscape processes.
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