Chapter 2
Landscape Learning in Relation to Evolutionary Theory

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Introduction

> *Human beings adapt not to their real environment but to their ideas about it, even if effective adaptation requires a reasonably close correspondence between reality and how it is perceived* Bruce Trigger (1989)

Landscape learning is a model that addresses how human groups gather and share environmental information from the perspective of colonization (Rockman 2003a, b). It has been noted by many scholars that the situation of a group being unfamiliar with an environment may have had substantial social and economic consequences and so may have had archaeologically visible traces (Anthony 1990, 1997; Beaton 1991; Bogucki 1979; Fedele 1984; Kelly and Todd 1988; Whittaker 1989). However, the process of learning itself and the underlying assumptions of how different types of environmental information may have been developed and transmitted over archaeologically visible time frames by different groups and different economies have not yet been fully examined.

The landscape learning model lays a framework for doing this by presenting a consistent process of information gathering in such a manner that it can be tested for in different historically contingent contexts. The objective of the landscape learning model is to determine whether, when, and how aspects of a previously unfamiliar environment become part of an ongoing social system, in other words, to identify environmentally related cultural change. Tests of the landscape learning model are still few (Rockman 2003b) and it is expected that the model will be expanded and refined in the future. Examination of the model and its underlying concepts to date, however, have shown it to be widely applicable to many contexts (for example, see Anderson 2003; Fiedel and Anthony 2003; Blanton 2003; Hardesty 2003; Roebroeks 2003; Steele and Rockman 2003; Tolan-Smith 2003;) and further that it fills a critical gap in linking the intangible realm of thought, perspective, and memory with the solid, traceable, measurable, and "mappable" archaeological record.

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The objectives of this volume are to examine the current state of thinking about cultural evolution. As the editors note in their introduction, archaeology is our sole means of examining the deep human past, and collected research over the history of the discipline has clearly demonstrated the long sequences of changes that have taken place from prehistory leading to our current major forms of social organization. As populations can be seen to continue through different sequential forms of social organization in many cases, the cultures they entail can be seen to have evolved following the concept of "descent with modification" (see also Eldredge, this volume; Spencer, this volume).

The theory of evolution began in the biological sciences with the examination of life forms and their interactions with and roles in their surrounding environments. The concepts of natural selection, survival of the fittest, and adaptation describe the long-term interactions of biological populations with those environments.

The relationship of the environment to cultural evolution is less clear. Anthropological theory has been moving away from the idea that the natural environment can determine cultural forms (see review in Dincauze 2000). Current understanding is that for a very long time humans have had, within parameters, the capacity to design their interactions with the environment.

Understanding how those design decisions are made and what their constraining parameters are is one of the primary objectives of cultural macroevolutionary theory (see Prentiss et al., this volume). As landscape learning addresses the role of thought, perception, and memory—all components of decision making—in human–environment interactions over time, it stands to be a useful tool in the archaeological macroevolutionary kit.

Gathering Environmental Information

Landscape learning occurs through the development of environmental knowledge. While there are many ways of dividing an environment into informational packages, the landscape learning model uses the following scheme of environmental knowledge (after Rockman 2003a):

- *Locational* geographic coordinates and physical characteristics of natural resources
- *Limitational* cycles and constraints of the local environment
- *Social* combination of locational and limitational knowledge into a form that is applied to ongoing practices and communicated among group members and between generations; i.e, share sense of "this is how we live here"

Locational knowledge describes fixed resources and other related geographic information, such as placement of a lithic outcrop, spring, or meadow with rich soils, pathway of a game migration, or distribution of sheltered caves or campsites with good visibility. Because locational knowledge is related to features and environmental characteristics that are generally fixed in space and time, gathering locational knowledge is likely the easiest portion of environmental knowledge to gather and may be learned quickly.

Collection of locational knowledge is contingent, however, on the economic and social needs of the given population. Rosenberg (1994) and other scholars in this volume (see Bettinger; Chatters; Mason; Prentiss; Prentiss et al.; and Rosenberg, this volume) use the term *Bauplan* to describe underlying structure and related constraints. Originally conceived as referencing the form of an organism, in cultural macroevolutionary theory it has been applied to the economic and social structure of a given population and the related opportunities and limitations of that structure. It is also a useful concept here. At the simplest level of consideration, resources or landscape features may only be recognized as such if they fall within the needs and material uses of the group, which are related to its *Bauplan*. For instance, van Andel and Runnels (1995) noted that the Mesolithic societies of Greece do not appear to have used upland plains but that these areas were later brought into use by early Neolithic farmers. At other levels of analysis, the process of identification of previously unused resources may slow occupation and use of a given ecozone by a given socioeconomic strategy (with a specific *Bauplan*), such as the time lag proposed by Tolan-Smith (2003) for the late Upper Palaeolithic colonization of maritime western Scotland, or may limit the range of identified available options in times of stress in common resources.

Limitational knowledge describes the periodicities of cyclical environmental characteristics and the constraints of the given environment for certain uses. For example, how much precipitation falls each year, in what forms, when, and how much does it vary from year to year? How many animals or plants can be hunted harvested each year without exhausting the respective populations. How stable are the game migration routes? How workable and reliable are the lithic materials for the range of tasks for which the given group uses them? Because limitational knowledge references phenomena that occur over time, it cannot be learned or confirmed instantaneously. Rather, the time necessary to develop or accommodate limitational knowledge is some function of the rate of change within its given identified cycle combined with the length of the generations within the subject population (Dean 1988; Minc 1986; Minc and Smith 1989; Smith 1988).

Recognition and use of limitational knowledge depends on the "dynamic scale ranges" of both environmental and social entities. As usefully developed from ecology for archaeological application by Hopkinson (2001, 2007a), dynamic scale range theory addresses the range of scales to which a given phenomenon of interest responds. Environments can be measured on multiple scales. For instance, as developed by Hopkinson (2001), a forest may be considered as either a dynamic entity in its own right, a constant setting within which an organism or population operates, or as inconsequential "noise" in major geological and geomorphological processes. Similarly, rainfall and temperature can be reported as daily, annual, or decadal averages. In turn, environmental entities respond primarily to rates of change that approximate their own reproductive cycle; for example, flower populations tend to reflect high frequency daily to seasonal variation in rainfall and sunshine, while trees are more likely to prosper or fail with longer period drought or fire cycles. However, they can reflect changes at much lower frequencies over the long term. The upper limit of the range is the level that can be considered a non-constraining constant in relation to the level of interest. The lower limit consists of "stochastic noise" that does not deliver a measurable signal to the level of interest. The dynamic scale range, therefore, includes both higher and lower frequency levels than the particular level or phenomenon of interest (Hopkinson 2001, 2007a) With respect to imitational knowledge, each instance of this aspect of landscape learning is most likely to reflect cycles that most closely match the life span of the element interacting with the cycle: annual planting procedures should respond to annual or similar precipitation and temperature variations, while settlement patterns respond to longer cycles, such as floods. Locations of annual planting, however, will likely correspond with at least some aspects of the longer term settlement patterns.

Social knowledge describes appropriate responses to gathered locational and limitational knowledge that have been shared among a group (horizontal transmission, after Boyd and Richerson 1985; Hewlett and Cavalli-Sforza 1986; Richerson and Boyd 2001, 2005) and passed to subsequent generations (vertical transmission) such that they form a collective sense of "this is how we live here." It is in fact such interaction of environmentally derived and socially shared activity that creates the phenomenon known as landscape (after Ashmore and Knapp 1999; Basso 1996; Tolan-Smith 1997). As social knowledge is the result of implementation of component locational and limitational knowledge, the time frame to develop it is the product of the time frames for the component knowledge and may be further modified according to the rates and forms in which it is shared, remembered, and stored in group-appropriate social forms (see Vansina 1985; Smith 1988).

Both locational and limitational knowledge can only be acquired from the environment through individual learning. Their transition into social knowledge occurs through social learning which in turn can be subject to the various biases (content-based or direct, frequency-based, and model-based) described by Richerson and Boyd (see definitions and background in Boyd and Richerson 1985; Henrich and Boyd 1998; Richerson and Boyd 2001, 2005).

Each type of knowledge can influence the development of the other two. Further, each type of knowledge can be updated at any time. For the sake of modeling and analysis, the landscape learning model is designed to analyze development of environmental knowledge with respect to a given resource from the perspective of colonization or first contact with an environment.

Landscape Learning and Colonization

Colonization has an uneasy place in macroevolutionary theory in light of the invoked role of colonization and diffusion in early culture-historical models of cultural change (Anthony 1990; Shennan 2000; Trigger 1989). The theoretical complexity of colonization and the important roles of different types of information flow as well as population movements have been more recently addressed and productively applied to multiple colonization case studies (Anthony 1990, 1997; Chapman and Hamerow 1997; Graves and Addison 1995). Colonization studies tend to present movement in one of two primary forms: point-and-arrow or streaming, which involves directed movement of a population along a relatively narrowly defined pathway over a relatively long distance between an origin a destination, and wave-of-advance (e.g., Ammerman and Cavalli-Sforza 1984), which posits relatively short distance movements across a relatively wide swath of environment. A third type of movement, leap-frogging, can be seen as a sort of combination of the two, involving multiple streaming movements between separated areas of similar environmental characteristics. There are many implications of these forms with respect to both motivating factors and potential for archaeological visibility (Anthony 1990, 1997; Beaton 1991; Jochim et al. 1999; Kelly 2003; Meltzer 2004; Webb 1998).

The point of interest for discussion here is the context they present for development of environmental knowledge when considered from the perspective of initial colonization. Point- and-arrow and leap-frogging forms require some form of predeveloped knowledge, at least to the extent that the target of colonization was identified, but describe a situation in which a wide range of knowledge structures (locational, limitational, social) may need to be updated rapidly or simultaneously. In wave of advance movement, in that it predicts shorter distance movements and greater likelihood of maintaining interactions with some portions of previously occupied environments, development of environmental knowledge can be seen as primarily cumulative, and may entail rapid locational knowledge updates with slower updates of limitational and social knowledge.

The development of environmental knowledge in the context of noninitial colonizations is more complex as it requires consideration of the nature of the relationships between previously established populations and the arriving population. Following a biogeographical approach developed in Rockman (2003a), the environmental knowledge relationships may be conceived as three barriers:

- *knowledge barriers* existence of usable previously collected information
- *population barriers* numerical population density and capacity with respect to the structure of existing and incoming economic systems and residence patterns (*Bauplan*); availability of niche space
- *social barriers* resident population's defense and information storage systems, including language

An initial colonization may have a high knowledge barrier—relatively little previously gathered information—but faces low/nonexistent population and social barriers. Contact between previous and immigrant populations with similar *Baupläne* may present lower knowledge barriers but potentially higher population or social barriers. Contact between populations with different *Baupläne*, such as agriculturalists and hunter-gatherers, will have high knowledge barriers and can be anticipated to have variable population and social barriers as well.

Colonization can also be a useful tool for macroevolutionary analysis because it depicts movement from somewhere to somewhere and therefore facilitates consideration of design decision constraints. Such consideration can be described at the micro-level from the perspective of environmental cognition and the use of schemata. An individual's initial contact with and movement through an environment proceeds by means of wayfinding (Golledge 1987, 2003). There are several means of wayfinding, including homing (continual updating) which may be likened to a wave of advance motion in which movement is perpetually referenced to previous movements and the intended destination; piloting (use of landmarks) which may be likened to point-and-arrow colonization in that it moves toward a known (if not immediately seen) destination with orientation provided by means of landmarks; and chunking, which may be likened to leapfrogging in that it breaks a relatively long route into identifiable and more easily negotiated segments. An individual's internal representation of routes traveled and to be traveled, places of origin, and intended destinations comprise the individual's cognitive map. As cognitive maps represent spatial experience, they are almost never complete and are updated as experience and information are added and the effective environment changes. Similarly, cognitive maps do not develop instantaneously. In instances where cognitive maps are incomplete, generalized information about environmental structure based on previous experiences elsewhere may be drawn upon, termed schemata, templates, frames of reference, scripts, and scenes (Golledge 2003). An example developed in Golledge (2003) from the built environment would be a modern urban dweller's knowledge of where to find an exit or restroom in a public building. A natural environment schemata may be that chert or flint may be found at topographic high points, particularly high erosional features (Rockman 2001b, 2003b).

Schemata, then, are patterns into which environmental information is anticipated to fit. If reality does not match imported schemata, then schemata may be updated or the environmental characteristic may be missed. In some instances, however, schemata or ways of doing things can suit a new environment better than the previous environment in which they were developed or find a new use or expression. Biological terminology calls such instances preadaptations or exaptations (see Gould 1991; Gould and Vrba 1982). Gamble (1993, 1999) has linked exaptation to the capacity shown by early hominids for global dispersal. This approach provides a link to landscape learning at the macro-evolutionary scale.

Landscape Learning at the Macroscale

Landscape learning is possible because of human behavioral flexibility. Behavioral flexibility makes it possible to encounter and adjust to new and different environments at a rate faster than can be allowed by physical evolution alone. In turn, the ability to respond successfully to new environments may have set in motion a feedback loop in which encountering novel environments and developing information about those environments supported more behavioral flexibility and a propensity to disperse and continue to adjust to new environments.

Potts's (1998) variability selection model posits that the uniquely wide range of human behavioral flexibility is an adaptation to environmental fluctuations of variable and increasing magnitude over the past 6 million years. Paleoenvironmental studies of a range of deposits dating from the Oligocene onwards have identified at least twelve cycles of environmental variation with cycles ranging from one to 100,000 years. The meshing and unmeshing of these multiple cycles with differing periodicities appears to have resulted in a particularly variable environment in which the influence of any given environmental cycle may have changed substantially from one cycle to the next, making its particular effects more difficult to track.

The variability selection model outlines the development of variability selection adaptations, which Potts defines as "complex structures or behaviors" that allow novel responses in unpredictable settings. These adaptations allow phenotypic variability that can vary with the environment in which the species finds itself, including versatile locomotor capabilities and dental structures, as well as the neurological capacity to process and respond to a range of external signals and social situations (Potts 1998). Following on this, the dynamic scale range of human physical capacities for cultural change can be defined per the wide range of environmental cycles included by Potts in the variability selection model. In turn, learning can be seen as an integral component of macroscale human physical evolution. The range of scales to which human cultures themselves respond is in need of additional investigation. The capacity to learn, however, can also be seen to have played a role in cultural development from hominid times onward.

The ability to behave flexibly and, in so doing, adjust social practice to local conditions, may have been a key component of the early hominid movements across the Old World. Currently, the number, paths, and rates of hominid dispersals out of Africa remain a focus of debate and study. Several recent studies (Ashton and Lewis 2002; Dennell 2003; Pavlov et al. 2004; Roebroeks 2003) have noted the patchiness of the premodern human record in Europe and argued that scattered sites over a long time frame cannot be taken at face value to indicate successful continuous occupation following a single initial colonization. Rather, it is more likely that there were repeated dispersals into and retractions out of different parts of Europe, perhaps on as coarse a scale as glacial–interglacial cycles, perhaps more frequently than that. Lahr and Foley (1994) have in turn suggested that diversity in the hominid and human populations indicates multiple dispersals of different hominid forms along different pathways within and out of Africa to the rest of the Old World. Dennell (2003), in his discussion of long and short chronologies of hominid movements out of Africa, pointed out that while it is possible with current dates to suggest a rate of 10 km/year for the *Homo erectus* dispersal from East Africa to Java, it is unlikely that colonization happened evenly at such a rate. The actual pattern of dispersal was likely much more punctuated.

The combined picture of these studies is that, given the fragmentary record that we have, it is simply not possible to postulate population pressure (as we are able to calculate it based on contemporaneous technology and paleoenvironmental evidence) as the sole motivation for these many dispersals. In other words, it is not possible to apply a simple wave-of-advance colonization model (after Ammerman and Cavalli-Sforza 1984) such that all intervening space was filled up as hominid colonization moved outward. Likewise, it is also not possible to equate hominid ranges with modern human ranges and related territorial behavior (see discussion of Paleolithic settlement at the end of Roebroeks et al. 1992). Therefore, it is also difficult to apply directly colonization "push-pull" analyses that are possible for the social underpinnings of more recent colonizations, particularly point-and-arrow or streaming-type colonizations (Ammerman and Cavalli-Sforza 1984; Anthony 1997). The impetus for hominid dispersals therefore falls outside traditional colonization models.

A proposal for the use of environmental information by early hominids by Gamble (1993), when combined with the prestige model-based pattern of information transmission from the cultural evolution model by Richerson and Boyd (2005) is a possible explanation for the major and relatively rapid early hominid dispersals. Briefly, the prestige model says that, insofar as imitation of others is a primary means of determining appropriate behavior, those individuals perceived to be successful are much more likely to be chosen as models to be imitated than individuals who are not perceived to be successful. Perception of success is critical, and imitation may focus on the outward, visible trappings or behaviors of the successful individual, not necessarily on the specific behaviors that made the individual successful (after Richerson and Boyd 2005).

Gamble's model is based on the situation of group fissioning to exploit patchy resources and unequal opportunities within the group to explore and acquire information. Gamble proposed that subadults, particularly subadult males, old enough to forage for themselves, would have been under pressure to leave the group temporarily by higher ranking older males to reduce rivalry for mates. These subadults collected important environmental information while "out of the house," which was then a source of information for the group as a whole when they returned. The key point for the expansion of the hominid range, or colonization, is that, as Gamble (1993) noted, "The impetus for exploration [came] not from some sort of adaptive curiosity. Instead it [stemmed] from the nature of the cooperative alliances, negotiated and contested between the core and peripheral members of the social group." In this model, environmental information was the social currency with which higher ranking males managed their role in the group and through which younger males gained their place in the group. A younger male with more and detailed environmental information to contribute might have moved further up the ranks than one with less or poorer information. If the prestige model-based transmission force is added to this, such that higher ranking explorers were imitated, more emphasis would have been placed on activities and skills related to exploration and, in turn, more geographic area may have been explored. Thus a social engine was in place that required exploration of more and more territory in order for the group order and functioning to be maintained. In this way, it was not population pressure but social pressure that may have driven early hominid dispersals (Anthony 1997; Fiedel and Anthony 2003). And the capacity to gather, retain, and transmit environmental information was what allowed this to happen.

Holons and Adaptive Landscape

The human capacity to respond culturally to the environment can be seen as a biological adaptation. In turn the cultural capacity to gather and share environmental information is an exaptation to global dispersal. Landscape learning, therefore, is an important link in the creation of a cultural landscape.

But what role does landscape learning play in the cultural changes of more complex societies with which much of macroevolutionary theory is concerned? The concept of adaptive landscape is applied by several other authors in this volume following on work by Wright (1932) (see Chatters; Prentiss; Prentiss and Lenert; Prentiss et al.; Spencer, this volume). In brief, it describes an array of peaks of variable heights and distribution within a plane of possible social and ecological relationships. Each peak represents a combination of relationships that is better suited—adapted—to its social and cultural environment than surrounding combinations of relationships. Macroevolutionary change occurs when a given population, group, culture, or society changes peaks and establishes a new combination of relationships. The potential benefit of changing peaks is that, ideally, the new peak is higher—more adapted—than the previously occupied peak. The challenge to changing peaks is that doing so may require moving across the valley between the peaks which is comprised of less adapted combinations of relationships.

The adaptive landscape is a useful concept for describing the situations that may precipitate cultural change. However, it does not describe how a given population, group, culture, or society comes to recognize that a change in peak is possible, necessary, or appropriate. Landscape learning is about how individual lines of information about different environmental traits, including fixed resources and cyclical patterns, are acquired. One additional theoretical tool developed from dynamic scalar range theory known as the *holon* is useful in considering and identifying the information and decision feedback loop that may play a role in peak switching and corresponding macroevolutionary change.

Hopkinson (2001, 2007; see also Koestler and Smythies 1969) defined a holon as

> Systematic clusters of strongly interacting components [that] can then be conceived as if they were a single entity from the point of view of the signals that they deliver to other components or clusters of components.

Holon boundaries are not necessarily equivalent to tangible boundaries such as the bark of a tree or edge of a flower patch and can include relative intangibles such as metabolic cycles and gene pools. Although holons are collections of system processes, they are bound by the same scalar rules such that ecosystems or learning systems cannot be comprehended by observations at a single scale or via a single holon (Hopkinson 2001, 2007a). A particularly cogent example of a holon for an archaeological context is the hydrologic changes in the American Southwest that contributed to the abandonment of the southern Colorado Plateau after A.D. 1250, as described by Dean (1988). The Great Drought that appears to have brought about the end of the Anasazi occupation of the area was not a single event but the intersection of low-frequency water table cycles, high-frequency drought cycles, and high-frequency agricultural practices which merged into a much lower frequency effect of devastating aridity.

With this example in mind, I suggest that the holon concept can be adapted for the purpose of investigating landscape learning, such that a collection of behaviors also may be considered a type of holon. A given set of behaviors or activities can generate an overall "signal" or level of adaptedness which then interacts with other groupings of behaviors of the given group, population, or species and with external holons found in the environment.

Drawing on Dean's (1988) example of the American Southwest and the dynamic scalar relationship between behavioral responses and environmental variability, the key point of behavioral holons is that they are a collection of individual practices. Within this collection, some previously established adaptations may work for some time in relatively similar environments. Problems develop for human groups when the outcome of all combined practices is no longer adapted to the new local conditions, and the relative adaptedness of the collective signal of the previous behavioral practices and environmental understandings exceeds local environmental tolerances.

For instance, a given behavior developed in a previous environment may be unsuitable as part of a set of behaviors or practices in a new environment. If, however, the results of the given behavior lie below the carrying capacity for that environment or do not immediately coincide with an unfavorable periodicity or downturn of that environment, then that relatively unsuitable behavior may persist within the overall behavioral system for an extended period of time. In turn, if the given behavior acts to bring a population into immediate and direct conflict with a new environmental periodicity or a periodicity downturn not previously encountered, then that particular behavior or the entire behavioral holon will come under direct and immediate selective learning pressure. As a result, individual practices of a behavioral system may be out of phase with each other with respect to their suitability in a given ecosystem. In other words, while a behavioral holon may appear adapted, individual component practices may not yet have come under selective pressure and so may themselves be poorly adapted. In turn, individual practices may be adapted, but the behavioral holon signal may be unadapted.

This is a critical addition to the landscape learning model as it allows consideration of time gaps between environmental experience and response. Lag time is built into the initial landscape learning model described above, with the essentially sequential movement of information from locational knowledge to limitational knowledge to social knowledge. Social knowledge in place at the time of colonization of an unfamiliar environment or major environmental change is unlikely to fully reflect the new environmental conditions and cannot be updated instantaneously; locational and limitational knowledge must be gathered and shared first. The holon concept brings this full circle and explains why it may appear that past groups did not learn their environments, or respond quickly enough to what may seem now to have been drastic environmental change. Humans have developed the ability to behave flexibly, and the landscape learning model suggests that we have the capacity to learn to live just about anywhere. What the holon concept provides is essentially the "brakes" on that flexible process by establishing thresholds for change. Given the capacities for imitation and transmission, learning and subsequent cultural change can happen at "blinding speed" compared to physical evolution (Richerson and Boyd 2005), but it has not necessarily been continuous. It is the development of multiple sets of social knowledge, interacting with and potentially changing one or more behavioral holons, that may account for the some of the punctuations in long-term cultural change.

Case Studies

As noted above, the landscape learning model is a tool in the macroevolutionary kit. In and of itself, at least insofar as its processes are currently understood, landscape learning does not account for the major transitions in cultural complexity that macroevolutionary theory addresses. To date, the two most detailed case studies of landscape learning describe development of locational knowledge by groups with stable *Baupläne*. These examples are summarized below, along with an additional hominid example as illustrations at different spatial and temporal scales of how the landscape learning process contributed to different groups' understanding of their place within their physical and adaptive landscapes.

Early Hominids

Following the discussion of Potts's (1998) variability selection model and the work of Gamble (1993) regarding early hominid dispersals out of Africa above, landscape learning can be seen to have been going on for 2 million years or more, and so the archaeological traces of landscape learning may be detectable from that time onward. Roebroeks (2001, 2003) has examined behavior and landscape learning in the context of the earliest peopling of Europe in the Middle Pleistocene. This setting presents many challenges: the relative sparseness of the archaeological record, the coarseness of our dating techniques for that time period, and the limitations they present with respect to identifying contemporaneous occupations, and the relative evolutionary "newness" of human behavioral flexibility. Roebroeks concluded that, insofar as landscape learning can be distinguished from physical evolution in this setting, it may be detectable only in the broad patterns of hominid presence and absence across glacial and interglacial cycles. For instance, locational knowledge may be deduced from the raw materials identified in individual or groups of sites (see raw material data compiled in Feblot-Augustins 1997). Development of limitational knowledge may be deduced from reuse of specific lithic raw material sources (see again Feblot-Augustins 1997) and evidence of successful hunting such as the carefully made and successfully used spears found at Shöningen (Dennell 1997; Thieme 1997).

The scope, nature, and persistence of social knowledge are difficult to define at this scale. Roebroeks (2003) noted that the form and content of early European sites suggest that the environmental capacities of the earliest Europeans were quite different from later, modern, landscape learners. Dennell (2003) furthered this view, noting that archaeological presence alone is not evidence of successful colonization. "Long" chronologies of hominid dispersals into Europe and the wider Old World (beginning before 1 million years ago) appear to be built on the record of intermittent events accomplished in favorable climatic intervals. "Short" chronologies (beginning after 1 million years ago) are based on records of more permanent colonization. Pavlov et al. (2004) noted, particularly with respect to early occupation of the northern reaches of Europe, however, that archaeologically visible occupation should be taken to represent at least a modicum of survival capability.

Hopkinson (2007b) proposes that, per these difficulties, the expansion of the Neandertal ranges in Europe transition to include high relief uplands in central and eastern Europe after 200,000 years ago was "not an evolutionary non-event". Rather it was, in other words, a macroevolutionary shift that had significant social landscape components. Strict review of sites dating prior to 200,000 years ago indicates that hominin groups avoided upland regions with broken terrain in Europe with occupation primarily, although not absolutely, distributed along the middle and lower reaches of river drainage systems in western Europe after a 200,000 years ago hominin occupation extended both eastward and upward into high-relief uplands. The distribution cannot be explained entirely by preservation issues or history of research; the shift in geography appears to be real. The eastern European landscape was characterized not only by a highly seasonal climate but also by a coarse-grained spatiotemporal distribution of resources. Millennial scale climatic fluctuations did not allow development of an optimally adapted consistent plant community but rather—similar to the effects of the variability selection forces on hominids—resulted in a patchwork plaid of vegetation patches that, given the regional characteristics of seasonality and topography, placed hominid-preferred resources relatively far apart. Lower Palaeolithic populations had use of fire and demonstrated ability to take medium-sized game, so barriers to the use of these areas were not strictly technological. Rather, they were social, cognitive, or both.

As developed by Hopkinson (2007b), the Neandertal Levallois technique combined two previously discrete lithic techniques: *façconage*, shaping of the core by removal of flakes, and *debitage*, production of sharpened flakes from a core, into a single technology; a change requiring what he terms an "incorporation of difference." The same incorporative process can be seen in the Middle Palaeolithic use of landscape. After 200,000 years ago, Neandertals incorporated "larger scales of heterogeneity into their effective systems of landscape exploitation" and lived life on larger spatiotemporal, conceptual, and practical scales. It is not yet clear whether these changes were cognitively based (physical evolution) or emergent factors due to population growth and transmission of practices. Hopkinson argues that these need not be exclusive; given the physical evolutionary basis of the learning capacity described above, this author concurs. The key point here is that the change in spatiotemporal use of coarse-grained landscape can be seen as a macroevolutionary shift in the capacity of hominid lifeways, represented by change in the distribution of sites and the use of integrated lithic technologies.

Recolonization of Britain at the End of the Last Ice Age

The archaeological record indicates that the British Isles were abandoned for up to 8,000 years during the last glaciation, which peaked at approximately 18,000 years ago. Hunter-gatherers returned to Britain by approximately 13,000 years ago, most likely from the direction of northern France (Rockman 2003b). The orientation of Britain in northwestern Europe, its changing shorelines during the late glacial, current distribution of radiocarbon dates, and comparative studies of late glacial migrations in Europe (Jochim et al. 1999) together suggest a point-and-arrow-type pattern (after Anthony 1997) for the British recolonization. Flint was an important lithic raw material in the toolkits of the late glacial hunter-gatherers of northwestern Europe, and therefore identification and use of new sources of flint during recolonization would have been a crucial component of environmental familiarization (Rockman 2003b). Although flint is widely distributed across the southern and eastern edges of England (Mortimore and Wood 1984), the flint-free north and west as well as changing vegetation cover during the late glacial (Walker et al. 1994; Walker and Harkness 1990; Whittow 1992) suggest that development of knowledge about its specific exposures and qualities would have been necessary.

Field survey and trace element analysis by means of inductively coupled plasma mass spectrometry (ICP-MS) identified five regions within the Cretaceous chalk flint formation of England and France and linked the majority of flint artifacts from five late glacial sites across England to flint sources in southwestern England, particularly the Salisbury Plain region (Rockman 2003b; Rockman et al. 2003). The current body of late glacial radiocarbon dates (see Barton 1997; Charles 1996; Fischer and Tauber 1986; Housley et al. 1997, 2000; Street and Terberger 1999) suggests that this procurement pattern may have persisted for several hundred years.

Although the identified flint exposures have a wide range of physical characteristics and vegetation causes substantial visual interference (even accounting for late glacial vegetation cover), the recolonizers of Britain appear to have successfully used wayfinding schemata that brought them at least into proximity to flint-bearing deposits. The earliest hunter-gatherers did not extensively use the first flint resources they would most likely have encountered along probable reentry routes in southern, southeastern, and eastern Britain (see shoreline reconstructions in Lambeck 1995). Rather, the landform characteristics of the tested British flint regions strongly suggest that southwestern England, particularly the northern Salisbury Plain region, was not only topographically the most "legible" (using a model based on Golledge

2003) of the tested regions, but it was also the most similar in navigational characteristics to one of the most probable colonization population source areas, the Paris Basin (Rockman 2003b).

Additional research is needed to identify the scope and rate of subsequent lithic resource use and change. The research on which this case study is based (Rockman 2003b) was designed to identify the establishment of lithic procurement systems during an initial colonization. The durability of the Salisbury Plain as a source area through the climatic changes of the Younger Dryas and into the Mesolithic has not yet been examined. The contribution this example makes to macroevolutionary investigation is the apparent absence of substantial adaptive change during and following major climatic and location shifts, the apparent success of lithic schemata and the persistence of the northern European Palaeolithic socioeconomic strategy; the thresholds of macroevolutionary change are higher.

South Pass City, Wyoming 1867–1872

The gold rush that centered South Pass City did not mark the first arrival of humans to the area. South Pass City was named for the geographic South Pass, which was the crossing point of the Oregon, California, and Mormon Trails over the Continental Divide, located 10 miles to the southwest. The gold rush miners were, however, the first to exploit the gold resources of the region. Hostility of the local Native American groups limited any information exchange (McDermott 1993), and so the miners had to overcome both knowledge as well as social barriers. The South Pass Gold Rush took place near the middle of a long series of mineral rushes in the American West (Hardesty 2003; Huseas 1991). Therefore, many of the South Pass miners arrived with schemata developed from previous mineral rushes and the capitalist frontier economy (*Bauplan*) had already accommodated setting up of mining ventures, including activities as diverse as bodies of mining law and provision of foodstuffs and lodging (Conlin 1986).

Early use of fauna at South Pass was split almost 50:50 between wild game and domestic animals, with a focus on larger mammals, such as deer, cattle, and pig. Within three years, faunal use had changed to a 25:75 wild to domestic fauna ratio, with notable numbers of wild and domestic fowl (Rockman 1995). Primary documents report several trips in which men from South Pass City attempted to hunt but failed as they did not know how to proceed or follow animals (Chisholm and Homsher 1960). Professional hunters worked in the area (Kingman to Johnnie, letter, 25 November 1869, South Pass City) although available data are not sufficient to determine the extent to which they were able to provision the town; overall patterns indicate a rapid establishment of an urban-style food supply chain.

Gold in the South Pass mining district is found principally in quartz veins. Some placer deposits have developed, but due to a lack of water the majority of effort focused on development of hard rock mining. It is now known that the South Pass area is geologically complex and has undergone at least four periods of deformation.

Gold-bearing rocks are generally confined to a broad shear zone approximately 8 miles long and 4 miles wide, but the current distribution of ore individual veins is very irregular and does not follow the major topographic trends of the area (Hausel 1984, 1989).

The distribution of mining claims in relation to the local gold-bearing geology shows that at least most of the miners did not grasp, or at least respond to, this effectively almost random placement of gold-bearing deposits. Rather, mining claims were organized in lodes, which are long lines of claims centered on gold discovery. The distribution of mappable claims shows that the lodes tend to follow the major topographic trends of the area (Rockman 2001a). One early report (Raymond 1870) likened South Pass ore to the gold-bearing quartz found in California.

Mining claims and census records show that it took approximately four months for miners to develop a functional familiarity with the process of gold claiming at South Pass (Rockman 2001a). It took approximately 30 years more to develop the scientific understanding of the gold-bearing geology of the area (Raymond 1870 in Rockman 2001a; see discussion of Hayden 1872; Knight 1901). This understanding did not come quickly enough for the town of South Pass City, however, as the area went economically by 1872 and as a residential community in 1967 (Huseas 1991; Huseas and Doherty 1984).

With respect to food, the miners and town inhabitants do not appear to have succeeded in developing even functional locational knowledge. With respect to gold, locational knowledge was gathered, and the limitations of the resource were keenly felt, as shown by the general collapse of the mining boom within 4 years. Social knowledge about the nature of the gold was developed only under a very different, non-gold rush, scientific situation. This may be seen as a failure of the landscape learning process. Such a failure, however, does not appear to have affected the behavioral holon of gold rush practice. Miners and others left the South Pass area for Montana, Colorado, and elsewhere in the West, and mineral rushes in this style continued in the West for another 30 years. Collectively, the “profitable” signal of the mineral rushes was so strong that it did not respond substantively to individual “failures” such as that of the Wyoming Gold Rush.

This example demonstrates the absence of appropriate landscape knowledge in multiple resource categories and the capacity of a complex social system to absorb and promote practices and situations that were economically maladaptive at the local and individual level.

Conclusions

Richerson and Boyd (2005) noted that

> Darwinian analysis reveals a mass of largely unexplored questions surrounding the psychology of cultural transmission and the biases that affect what we learn from others. Small, dull effects at the individual level are the stuff of powerful forces of evolution at the level of populations. Understanding rather precisely how individuals deploy their kit of imitation

> heuristics is necessary to understand the rates and direction of cultural evolution, and work on the problem has hardly begun.

The same holds true for landscape learning. It is possible to study human knowledge structures in the present and model environments of the past, but an archaeology of environmental learning is necessary to assess the "small, dull" details of what people did when in both new and old places, how they moved from one to the other, and how those details changed over space and time.

Landscape learning is possible because of behavioral flexibility, which in turn evolved in response to unpredictable environmental fluctuations (Potts 1998). The combination of behavioral flexibility and social learning processes (prestige-biased) (Richerson and Boyd 2005) create a viable explanation for the dispersal of hominids out of Africa (after Gamble 1993).

The phenomena of dispersal and colonization have interesting roles in macroevolutionary investigations due to early culture-historical explanations for cultural change. Recent theoretical developments make them a useful starting point for assessing population-environment interactions, as a colonization approach requires examination of assumptions about environmental interaction decisions and what the constraining parameters of such decisions may be. At the micro-level, such parameters may be described as schemata (Golledge 2003). At the macroscale, they are preadaptations or exaptations (Gould and Vrba 1982; after Gamble 1993).

Landscape learning proceeds through the development of locational knowledge, limitational knowledge, and social knowledge (Rockman 2003a, b). Locational knowledge is constrained by *Bauplan* (see Rosenberg 1994, this volume), limitational knowledge responds dynamically to appropriate scales of environmental change (after Hopkinson 2001, 2007a). Social knowledge, the composite of shared locational and limitational knowledge, develops through social learning and is thereby subject to the multiple biases of the transmission process (Boyd and Richerson 1985; Richerson and Boyd 2005).

Compilation of responses to environment interaction may be one source of information that indicates a shift in adaptive peak is necessary or appropriate (Wright 1932) (see also Spencer, this volume). Behavioral holons (after Hopkinson 2001, 2007a) describe the feedback between environmental information and social response, which creates the lag time or punctuation in group-level environmental learning.

Macroevolutionary shifts in the Middle Palaeolithic may have been based in the capacity to incorporate difference and are archaeologically visible in the expansion of range and use of geography (Hopkinson 2007b). In more recent examples, landscape learning can be seen to be decoupled from changes in social complexity. Rather, examples of Upper Palaeolithic colonization show the capacity of hunter-gatherer systems to persist in unfamiliar but similar environments (Rockman 2003b) and for complex economies to absorb, at least initially, expensive economic failures (Rockman 1995).

Taken together, the combination of development of environmental knowledge structures and the processes of holon feedback described by the landscape learning model has great relevance to our efforts to understand the patterns of long-term human–environment interaction and inform studies of macroevolution. By considering the periodicities of relevant aspects of the environment and individual–group information transmission patterns necessary for developing social knowledge and adjustment of practices to local environmental settings, it is possible to think in a new way about stops, starts, and continuity in the archaeological and cultural record. As well, understanding more clearly the circumstances under which hominids and humans appear to have learned or not learned their environments has implications not only for our understanding of the past but may also provide useful information about how we will (or should) adjust our own present-day environmental knowledge and practice to environments we may encounter in the future.

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