January 2010

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J Archaeol Res (2010) 18:241–288
DOI 10.1007/s10814-010-9038-6

Landscape and Environment: Insights from the Prehispanic Central Andes

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Published online: 2 February 2010

Abstract Attention to human–environment relationships in the central Andes has a long history. Although the area is not a neat microcosm of the globe, wholly representative of worldwide trends in the archaeology of human–environment interactions, it has been the site of both seminal investigations in archaeology and a substantial body of recent work that investigates themes of broad archaeological relevance. Specifically, central Andean environments have been variously conceived as structuring, modified, and sacred. These approaches to some extent reflect broad trends in archaeology, while also suggesting directions in which the archaeology of human–environment interactions is moving and highlighting archaeology's relevance to discussions of contemporary human–environment interactions. This article characterizes concepts that are key for describing central Andean environments and considers the ways in which the particular ecology of the central Andes has informed archaeological research in the region. The example of the central Andes highlights the importance of understanding environments as dynamic, considering both geomorphic and anthropogenic contributors to that dynamism, and examining both ecological ("environment") and ideological ("landscape") implications of archaeological landscapes.

Keywords Andes · Environment · Landscape · Peru

Introduction

Attention to human–environment relationships in the central Andes has a long history. Much of this interest is due to perceptions of many Andean environments as marginal for subsistence, with resultant surprise at their abundant capacity to

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support substantial human populations. The tight packing of diverse environments and the dramatic climatic variability typified by El Niño also have drawn attention. As a result, the central Andes have been the site of both seminal investigations in archaeology and allied fields (e.g., Moseley 1975; Murra 1972; Troll 1968; Willey 1953) and a substantial body of recent work that investigates themes of broad archaeological relevance. In recent work focused on the archaeology of human–environment interactions, Andean environments variously have been conceived as structuring, modified, and sacred. These three approaches reflect general trends in the archaeology of human–environment interactions. Also recognized is the need for integrative approaches in the archaeology of human–environment interactions (e.g., Fisher and Feinman 2005; Fisher and Thurston 1999; van der Leeuw and Redman 2002).

Here I offer a brief characterization of key concepts for describing Andean environments and consider the ways in which the particular ecology of the central Andes has informed archaeological research in the region. I begin with an overview of archaeological approaches to human–environment dynamics and a brief description of central Andean environments and ecology, before turning to a synthesis of archaeological research on human interactions with these environments. Focusing on the literature of the last ten years that covers the Holocene period in the central Andes, I employ the three categories of structuring, modified, and sacred environments to examine the ways in which the archaeology of the central Andes has engaged issues of human–environment interactions. I group as structuring environments archaeological approaches that identify environmental factors as important drivers of cultural parameters and/or change. The category of modified environments includes those studies that focus on anthropogenic landscape change. In the category of sacred landscapes are studies that emphasize the ritual and ideological dimensions of central Andean landscapes.

The long tradition of characterizing central Andean environments as structuring has parallels to ecological issues in Americanist archaeology generally and has produced broadly influential publications (e.g., Kosok 1965; Moseley 1975; Murra 1972; Willey 1953). A significant thread of this research is the impact of environmental perturbations on human populations—particularly the implication of environmental factors in cultural collapse, including both long-term climatic shifts and abrupt events, of which El Niño is the most salient. Focus on abrupt events also has included interest in prehistoric earthquakes, tsunamis, and massive debris flows (often El Niño-related) and volcanic eruptions.

Increasingly the converse has been emphasized—the influence of the human occupants on Andean environments. This interest consists of work that highlights human impacts on environments and, increasingly, research that focuses on deliberate anthropogenic modification of environments, generally intended to improve subsistence possibilities and/or manage risk.

A parallel, and often wholly distinct, focus is the description of sacred landscapes in the central Andes and the analysis of Andean environments as cosmologically significant to their inhabitants. Based on ethnographic and ethnohistoric analogy, this body of work now offers an array of examples that convincingly argue for the antiquity of modern and contact-period Andean beliefs and rituals associated with the environment.

This diverse array of archaeological approaches to environment and landscape in the central Andes highlights three broadly applicable lessons: (1) the relevance of environmental dynamism, (2) the pervasiveness of anthropogenic modification of environments, and (3) the importance of considering setting in both ecological and ideological terms (as, that is, both "environment" and "landscape"). I return to these issues in the final section, where I also consider the ways that research on prehispanic human–environment interactions in the central Andes fits a broader archaeological focus on long-term human–environment interactions (French 2007; Hayashida 2005; Kirch 2005; McGlade 1995; van der Leeuw and Redman 2002), with particular attention paid to issues of sustainability and resilience (Peeples et al. 2006; Redman 2005).

Landscape and environment in recent archaeological perspective

The terms "landscape" and "environment" have been associated with rhetorically opposed intellectual approaches to the geographic settings of archaeological sites. To situate the literature from the central Andes within broader debates in archaeology, I briefly explore this distinction before turning to approaches to environment and landscape.

Van der Leeuw and Redman (2002, pp. 600–601) suggest a tripartite division, arguing that the history of academic approaches to human–environment interactions reflects changing perceptions of the nature of those interactions. They loosely define three (more or less successive) types of study of humans in their environments, reactive, proactive, and interactive, roughly defined as understanding humans (1) as at the mercy of their environments, and cultural development as conditioned by environmental potentials and constraints, (2) as masters of all they survey, shaping environments to fit cultural needs and desires, and (3) as existing in creative tension with their surroundings. The anthropological question underlying these shifting approaches is fundamental: whether humans structure their environments or are structured by them. A third alternative, that the two are recursively linked, also has found favor in recent literature (e.g., Fisher and Feinman 2005; Redman 2005).

Archaeology has taken an interest in human environments almost since its origins, primarily as resource endowments and influences to which cultures had to adapt. Interest in various cultural evolutionary schema necessitated attention to environments as selecting influences. These functionalist and materialist approaches focused primarily on the relationship between geography and economy, theorizing that evolutionary logic dictated the importance of the environment as a structuring factor in cultural development (Trigger 1971). The related "cultural ecology" approach represented a more holistic, less strictly economic, interest in the environment, as did the ecosystems approach prominently advocated by Binford (1962) and Flannery (1972) (see Preucel and Hodder 1996 for a summary).

The basic critique of these studies as failing to account for many of the elements (gender, class, and faction) that shape human social behavior was forcefully articulated by Brumfiel (1992). She drew on earlier critiques that faulted ecological approaches for ignoring symbol and meaning and equating simple and generic "space" with complex and contingent "place" (see Hodder 1987 in archaeology; Tuan 1974 in geography). Ecological approaches also had their more sympathetic critics (e.g., Hastorf 1990; Jochim 1990), who advocated reform of ecological approaches rather than their abandonment.

Subsequent and more radical critiques (Thomas 2001; Tilley 1994) present a general backlash against materialist and functionalist approaches to human culture (see Preucel and Hodder 1996), forming part of the postprocessual critique (Trigger 1989). This body of work, generally termed landscape archaeology, deliberately focused on the term "landscapes" rather than "environments" as a means of focusing on the human experience of the environment and emphasizing the legacy of anthropogenic activity that shaped local environments (Ashmore and Knapp 1999; Tilley 1994; Ucko and Layton 1999). In its more extremely postmodern forms, this approach came to consider environments as of interest primarily if not exclusively as cultural constructs, significant more for what they reflected about human social activity than for what might be understood about environmental influences on such activity (e.g., Bender 1993; Thomas 2001; Tilley 1994). Tilley's label of "phenomenological" captures the emphasis on the experience of the environment characteristic of this work, which also includes significant critiques of the Cartesian nature/culture dichotomy (e.g., Ingold 2000). As Fisher and Thurston emphasize, however, landscape archaeology by no means represents a coherent intellectual approach but rather a diversity of approaches to analogous materials, namely, human–environment dynamics in various contexts (Fisher and Thurston 1999, p. 630).

This observed diversity is characteristic of environmental as well as landscape approaches. A recent revival of environmentally oriented approaches has taken many of these critiques on board, while reasserting the importance of human–environment interactions as a research focus (see Scarborough 2003). The importance of such a focus, these scholars argue, is both theoretical and a function of archaeology's potential to inform contemporary policy making (Fisher and Feinman 2005; Hayashida 2005; Kirch 2005; Redman 2005).

The Americas have been an important stage for this debate and a laboratory for testing its postulates. They are a usefully bounded entity, both spatially and chronologically, as Lentz (2000, p. 3) points out: "the Western Hemisphere represents a discrete and easily defined geographic unit with a large landmass uninhabited by humans for most of its evolutionary history." A confounding factor in the Americas—though not unique to the Western Hemisphere—has been the legacy of Western suppositions about the continents colonized by Europeans in the 16th century. Denevan (1992) neatly articulates this problem by terming it the "pristine myth," and Stahl (1996, p. 106) cautions against "applying 'pristine,' 'virgin,' or 'natural' as attributes of a pre-Columbian America…[or] uniformly ascribing 'environmentalist,' 'conservationist,' or 'ecological' ethics to its inhabitants." Changing perceptions in recent decades of the size and sophistication of indigenous populations of the Americas before European arrival (e.g., Denevan 1992; Lentz 2000; Verano and Ubelaker 1992) have recast both understandings of the extent of the pre-Columbian anthropogenic footprint and notions of the anthropological significance of that footprint. This revision also has begun to appear in the popular press (e.g., Mann 2005).

In the central Andes, the emphasis of this research trend has been on the long-term successful human occupation of diverse Andean environments, many of which have traditionally been considered marginal for human subsistence and circumscribed by environmental or sociopolitical factors. Although the term "marginal" has been problematized, the constraints that Andean environments impose are real; their thresholds for supporting intensive and/or extensive human occupation are generally near, and the perturbations they experience are dramatic. Perhaps, as a result, environmental setting is rarely wholly backgrounded in the Andes. The specific character of Andean environments has been a focus whether interest has been in the influence of environmental settings on sociopolitical forms, attention to their anthropogenic modification, or interpretation of their cosmological and quotidian meanings to their inhabitants. The result is a rich and diverse array of research on human–environment interactions in central Andean prehistory, producing several insights important to the archaeology of human–environment interactions generally.

Andean ecology

The central Andes, stretching from northern Chile into Ecuador, are notable for the way the steep topography has resulted in highly diversified ecological zones within short horizontal distances. East-west transects across the central Andes pass from the Amazon Basin to the Pacific Coast in under 200 km, crossing peaks that can crest 6000 m and multiple ecological zones. These were classically described by the geographers Pulgar Vidal (1981), Tosi (1960), and Troll (1968); Troll seems to be the conceptual forebear of Pulgar Vidal and Tosi, as well as Murra (Gade 1996). Inspired by von Humboldt's pioneering work (Mathewson 1986) and drawing on more recent work on "man-land" relationships in the Americas by Sauer (e.g., 1956, 1958), these geographers drew on both scientific description of ecological zones, defined by such geographic factors as altitude, temperature, and insolation (Tosi and Troll), and the identification and formalization of indigenous ethno-classification of altitudinal and ecological zones (Pulgar Vidal). These coarse-grained, sweeping studies have been complemented by detailed examinations of the ecological situations of particular communities (e.g., Brush 1976, 1977; Mayer 1979; Winterhalder and Thomas 1978). Theoretical refinements have problematized the rigid boundaries and sharp contrasts of the zone model, accepting its broad parameters (e.g., Dollfus and Lavallee 1973; Zimmerer 1999; Zimmerer and Langstroth 1993) while emphasizing patchy local mosaics rather than large uniform zones.

Although the concept of altitudinal bands continues in use, other key factors such as aspect, slope, soil depth and quality, local mean temperature, and frost risk create local patchiness and overlap of vegetative zones (e.g., Dollfus and Lavallee 1973; Gade 1996; Zimmerer 1999). The picture is even more complicated with regard specifically to crop distributions, as their dispersal owes much to agricultural preference and practice, land tenure, land modification, and variability in environmental factors (Gade 1996; Zimmerer 1999). In addition, as Craig (1985) points out, these systems are vegetative zones rather than truly ecological ones in that for practical reasons only flora, and not fauna, is considered.

This highly variegated landscape is subject to significant seasonal and annual variability in precipitation. Rainfall in the highlands is rare in the austral winter and common in the austral summer, while on the coast moisture-bearing fog is a near-constant feature of the austral winter. Interannual variability in precipitation can be dramatic and further emphasized by the roughly decadal occurrence of El Niño events that bring torrential rain to the coast and drought to much of the highlands. This modern pattern appears to have been established by approximately 3000 BP (see Sandweiss et al. 2001, 2007). The regionally variable effects of El Niño events—heavy rains are often highly localized—are as yet little explored in the archaeological literature.

Scholarship dedicated to the adequate description of the particular geography of the Andes dates back to Guaman Poma de Ayala, who tried to convey the particularities of the Andean landscape in his 17th century missive to Spain: "And you should know that this kingdom is folded like a starched collar, that there are places half a league apart as the crow flies; where to descend to the river is four leagues, and to ascend the other side another four leagues" (Guaman Poma de Ayala 1616; my translation). Guaman Poma, like many human and cultural geographers who followed him, was interested in the topography of the Andes primarily for the human implications of such a landscape. Similarly, the descriptive environmental classification schemes developed by Pulgar Vidal, Tosi, and Troll were explicitly focused on the agricultural and subsistence implications of Andean geography.

These attempts to characterize the capacities and constraints of the Andean landscape were to be complemented—and in some cases challenged—by archaeological investigations of past human occupation and use of that landscape. Whereas the geographical studies generally examined either current species distribution or some measure of environmental potential (calculated using some combination of mean annual precipitation, mean annual temperature, potential evapotranspiration, latitude, and elevation) and inferred human use, archaeological studies have attempted to empirically examine past human use of the landscape and critically assess generalized arguments about environmental potential or the antiquity of species distributions. These contrasting approaches—privileging abstract characterization of some calculable natural potential versus assessing empirical evidence of past use—also are described by Dollfus (1982, p. 39) with regard to historical, rather than archaeological, research.

Archaeological research also has served to challenge characterizations of Andean environments as marginal by appealing to evidence of their intensive use in prehistory (e.g., Erickson 2000; Rick 1980). This disjunct between calculated environmental potential and evidence of past use is what led to Troll's failure to recognize the legacy of human activity in modern distributions of Andean flora (see Gade 1996, p. 313). In contrast, Budowski (1968) offered an early warning against incautiously inferring past species distributions from present ones, given the various forms of anthropogenic disturbance that affect modern distributions, and Ellenberg (1979) provocatively argued for prehistoric human deforestation of the high Andes. Recent research on this issue (Fjeldså 2002; Kessler 2002) continues to suggest that the current distribution of *Polylepis* trees more likely reflects millennia of anthropogenic disturbance than the natural species range. This discussion of the relationship between resource endowment and anthropogenic impact mirrors the conceptual contrast in archaeological approaches to human–environment interactions between structuring and modified environments.

Structuring environments

Attention to the ecology of the central Andes has been accompanied by archaeological attempts to characterize the effects of the environment on human occupation. The implications of vertical ecological zonation for Andean archaeology were most famously explored in Murra's elaboration of the concept of the vertical archipelago, the pattern of direct control by past Andean societies of territory in multiple altitudinal zones (Murra 1972, 1985a, b); this work inspired a substantial body of further research on the linkages of altitudinal zones in the central Andes (e.g., Masuda et al. 1985; Van Buren 1996), including Salomon's (1985, p. 527) important exhortation to consider "the interplay between biosystem and system of cultural meanings."

Murra was by no means, however, the first to consider the implications of Andean geography for the region's pre-Columbian peoples. Here I review archaeological interest in the influence of Andean ecology generally and look also at arguments for the impact of changing environmental conditions on past peoples. I focus particularly on paleoclimate, El Niño, and catastrophic events before turning to the ongoing debate over specific links between environmental change and cultural florescence or collapse.

Most simply, the critical importance of water as an agricultural resource in Peru's coastal valleys has long been recognized—indeed, its centrality is so obvious, the constraint so apparent, that it may have been this that stimulated early attention to ecological factors in Peruvian archaeology. Even some of the early attempts to define Peru's culture history included attention to environment and ecology. Kroeber's (1927, p. 652) recognition of the potential for prehispanic irrigation agriculture in Peru's coastal valleys, for instance, led him to note, in an article otherwise dedicated to the cultural typology of Peruvian prehistory, that "the difference between Coast and Highland is great enough to make the environments a definite element to be considered in the tracing of cultural relations."

In addition, water as a limiting resource was central to the selection of a coastal valley as the unit of analysis for the first great investigation of cultural ecology in Peru, the Virú Valley Project (Willey 1953). A similar focus on the importance of fresh water as resource explicitly informed Kosok's work (1965) and prompted focus on the Peruvian coast as a laboratory for examining Wittfogel's (1957) hypotheses on the links between irrigation and developing social complexity (e.g., Billman 2002; Eling 1987; Golte 1980; Hayashida 2006; Moseley and Deeds 1982; Netherly 1984; Price 1971; Steward et al. 1955).

The seminal contribution of Moseley's (1975) *The Maritime Foundations of Andean Civilization* [subsequent challenges (Bonavia 1982; Osborn 1977; Raymond 1981; Wilson 1981) notwithstanding] was the recognition of the role that marine resources played in altering the environmental constraints of the Andean coastal desert; it was an eminently environmentally oriented work. Moseley's suggestion that marine resources offered a means of escaping the tight resource constraints of the Peruvian coast added a dimension to studies of human–environment interactions on the coast that the majority of subsequent work has embraced (even when not agreeing with Moseley's conclusions, e.g., Haas and Creamer 2006; Shady Solís 2006). This emphasis on subsistence informed a large body of archaeological research that approached environment as important both as resource base for early foraging populations and as a basis of production for increasingly complex sociopolitical formations (e.g., Osborn 1977; Quilter and Stocker 1983; Quilter et al. 1991; Wilson 1981). Resource intensification, generally either through changing technology of exploitation (e.g., Parsons 1970; West 1981) or landscape modification (e.g., Denevan 2001; Kolata 1991; Lentz 2000; Schreiber and Lancho Rojas 2003), also became an important focus (this is explored further below). Attention to ecological factors in the highlands, where ecological limits are less stark, was similarly early. Tello suggested a link between the diversity of Andean environments and the development of prehistoric cultures as early as 1930 (Tello 1930, p. 260).

This attention to environment as something more than backdrop for culture history was somewhat prophetic. As ecologically oriented archaeology found an important natural laboratory in the coastal valleys of Peru, so eventually would it look to the highlands, in the form of both catchment-area settlement archaeology (e.g., MacNeish et al. 1983; Parsons et al. 2001) and excavation of deeply stratified deposits covering the entire history of human occupation of the high Andes, from the Late Pleistocene to the present (e.g., Lavallee 1982; Lynch 1967, 1980; MacNeish 1979; Rick 1980). This long time span focused interest on environmental—particularly climatic—changes, especially the Pleistocene-Holocene transition and glacial retreat (Aldenderfer 1999; Cardich 1985; Dollfus and Lavallee 1973; Hansen et al. 1984; Nuñez et al. 2001; Rick 1983; Wright et al. 1989).

The south-central Andes have been a major focus of such work, with particular attention on the Lake Titicaca Basin. In addition to archaeological interest in such major sites as Pukara and Tiwanaku, and ethnohistoric accounts of the region's importance to the Inca empire, the Titicaca Basin has been the focus of a wide variety of paleoclimatic studies (e.g., Abbott et al. 1997a; Baker et al. 2001; Paduano et al. 2003; Tapia et al. 2003; see Fig. 1). These studies employ a wide variety of proxies (e.g., pollen, organic C content, $\delta^{18}O$; see Table 1) to reconstruct temperature and precipitation histories of the region. As I discuss in detail below, these paleoclimatic studies cover time periods of intense archaeological interest, and the articulation of paleoclimatic and archaeological sets of data has generated ongoing debate.

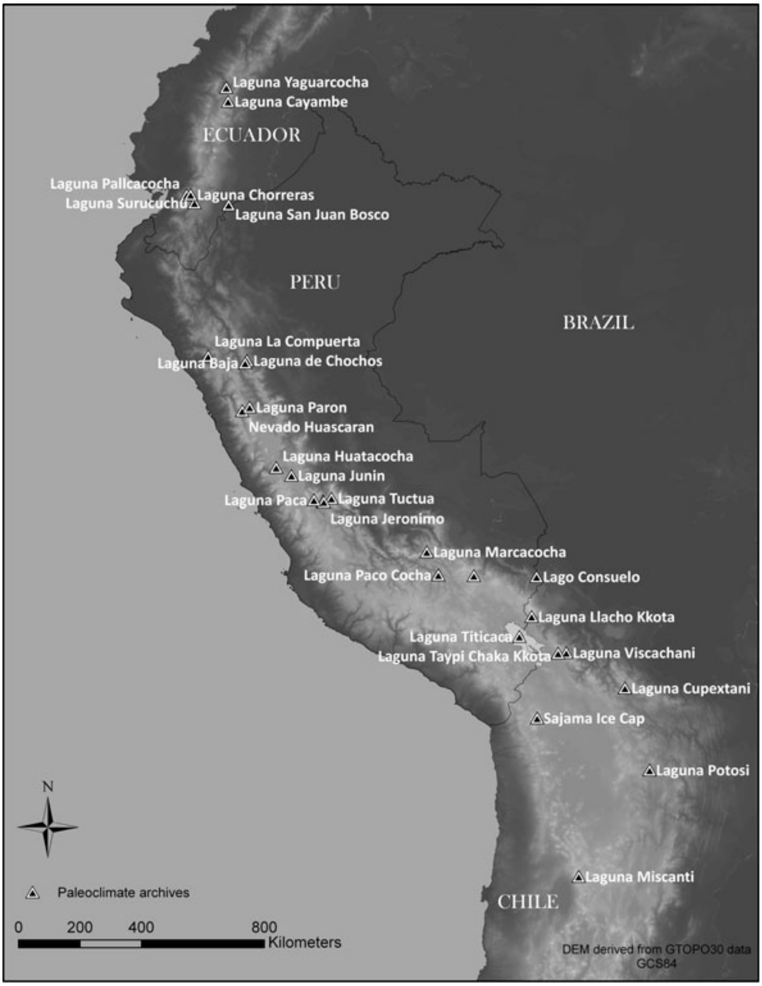

Fig. 1 Geographic distribution of published paleoenvironmental archives in the central Andes. Paleoenvironmental reconstructions based on biota in archaeological contexts are not included; several distinct archives have been extracted from Lake Titicaca

Research in the highlands, like that on the coast, often included significant interest in how (and whether) highland environmental resources provided a basis for human subsistence (e.g., Lynch 1967, 1971; Rick 1983). Dollfus and Lavallee (1973) foreshadowed this interest in 1973 (p. 76, my translation): “The variety of ecological niches … makes the great tropical mountains a geographic space that is easily exploited by human groups possessing limited technology.” Similar interest in the vertical variegation of Andean resources—and, hearkening back to Murra, their complementarity—is evident in subsequent work (Aldenderfer 1993; Dollfus 1982; Hastings 1987; Masuda et al. 1985; Shimada 1987; Stanish 1989). Both archaeological and ethnographic research has attended to what is distinctive about

Table 1 Paleoenvironmental archives in the central Andes

Location	Type of archive	Timespan[a]	Coordinates	Reference	Proxies
Lago Consuelo	Sediment cores	48,000 BP–present	13°57S, 68°59W, 1360 m asl	Bush et al. 2004	Pollen
Laguna Baja	Sediment cores	14,100 BP–present	7.70°S, 77.53°W, 3575 m asl	Hansen and Rodbell 1995; Weng et al. 2004	Pollen, organic carbon, magnetic susceptibility, charcoal, bulk density, grain size
Laguna Cayambe	Sediment cores	7200 BP–present	0.03°S, 78.03°W, 4350 m asl	Graf 1981; Weng et al. 2004	Pollen
Laguna Chorreras	Sediment cores	17,000 cal BP–present	2.76°S, 79.13°W, 3700 m asl	Hansen et al. 2003; Rodbell et al. 2002; Weng et al. 2004	Pollen, magnetic susceptibility, charcoal
Laguna Cupextani	Sediment cores	11,000 cal BP–present	17°13′S, 66°24′W	Abbott et al. 2003	Sediment stratigraphy, lithology, bulk density, C content, biogenic silica, diatoms, $\delta^{18}O$
Laguna de Chochos	Sediment core	17,000 cal BP–present	7°38.175′S, 77°28.473′W, 3285 m asl	Bush et al. 2005	Magnetic susceptibility, pollen, bulk density, charcoal
Laguna Huatacocha	Sediment cores	12,150 BP–present	10.77°S, 76.62°W, 4500 m asl	Hansen et al. 1984; Weng et al. 2004	Pollen
Laguna Jeronimo	Sediment cores	10,960 ± 390 BP–present	11°47′S, 75°13′W, 4450 m asl	Hansen et al. 1994	Pollen
Laguna Junin	Sediment cores	43,000 BP–present	11°00′S, 76°10′W, 4100 m asl	Hansen et al. 1984, 1994	Pollen
Laguna Junin	Sediment cores	18,000 BP–present	11°S, 76°W, 4100 m asl	Seltzer et al. 2000	$\Delta^{13}C$, $\delta^{18}O$
Laguna Juntutuyo	Sediment cores		17°33′S, 65°39′W	Abbott et al. 2003	Sediment stratigraphy, lithology, bulk density, C content, biogenic silica, diatoms, $\delta^{18}O$
Laguna La Compuerta	Sediment cores	30,000 cal BP–present	7°30′S, 78°36′W, 3950 m asl	Weng et al. 2006	Pollen, charcoal, magnetic susceptibility, bulk density
Laguna Llacho Kkota	Sediment cores	11,000 cal BP–present	15°07′S, 69°08′W	Abbott et al. 2003	Sediment stratigraphy, lithology, bulk density, C content, biogenic silica, diatoms, $\delta^{18}O$

Table 1 continued

Location	Type of archive	Timespan[a]	Coordinates	Reference	Proxies
Laguna Marcacocha	Sediment cores	4150 cal BP–present	13°13′S, 72°12W, 3355 m asl	Chepstow-Lusty et al. 1998, 2003	Pollen
Laguna Miscanti	Sediment cores	22,000 BP–present	22°45′S, 67°45′W, 4140 m asl	Grosjean et al. 2001	Pollen, sediment stratigraphy
Laguna Paca	Sediment cores	5305 ± 90 BP–present	11°43′S, 75°30′W, 3600 m asl	Hansen et al. 1994	Pollen
Laguna Paco Cocha	Sediment cores	14,600 cal BP–present	13°54′S, 71°52′W	Abbott et al. 2003	Sediment stratigraphy, lithology, bulk density, C content, biogenic silica, diatoms, $\delta^{18}O$
Laguna Pallcacocha	Sediment cores	15,500 cal BP–present	2°46′S, 79°14′W, 4060 m asl	Hansen et al. 2003	Pollen, magnetic susceptibility, charcoal
Laguna Pallcacocha	Sediment cores	15,000 cal BP–present	2°46S, 79°14W, 4200 m asl	Moy et al. 2002; Rodbell et al. 1999	Sediment stratigraphy, bulk density, magnetic susceptibility, C content
Laguna Paron	Sediment cores	2000 BP–present	9°S, 77°44′W, 4200 m asl	Seltzer and Rodbell 2005	Delta progradation
Laguna Pomacocha	Sediment cores	9820 ± 130 BP–present	11°45′S, 75°15′W, 4450 m asl	Hansen et al. 1994	Pollen
Laguna Potosi	Sediment cores	11,800 cal BP–present	19°38′S, 65°41′W	Abbott et al. 2003	Sediment stratigraphy, lithology, bulk density, C content, biogenic silica, diatoms, $\delta^{18}O$
Laguna San Juan Bosco	Sediment cores	33,000–18,000 BP	3°3′45″S, 78°W, 970 m asl	Bush et al. 1990; Colinvaux et al. 1997	Pollen
Laguna Seca	Sediment cores	12,000 BP–present	18°11′S, 69°14′30″W, 4000 m asl	Baied and Wheeler 1993	Pollen
Laguna Surucuchu	Sediment cores	11,870 ± 220 BP–present	3.06°S, 79°W, 3180 m asl	Colinvaux et al. 1997	Pollen
Laguna Taypi Chaka Kkota	Sediment cores	14,000 cal BP–present	16°12′S, 68°21′W, 4300 m asl	Abbott et al. 2003	Sediment stratigraphy, lithology, bulk density, C content, biogenic silica, diatoms, $\delta^{18}O$

Table 1 continued

Location	Type of archive	Timespan[a]	Coordinates	Reference	Proxies
Laguna Titicaca	Sediment cores	3500 BP–present	16S, 69W, 3800 m asl	Abbott et al. 1997a	Sediment stratigraphy, lithology
Laguna Titicaca	Sediment cores	25,000 cal BP–present	16S, 69W, 3800 m asl	Baker et al. 2001	Magnetic susceptibility, diatoms, $\delta^{13}C$
Laguna Titicaca	Sediment cores	5000 cal BP–present	16S, 69W, 3800 m asl	Binford et al. 1997	$\Delta^{18}O$ (otherwise as Abbott 1997)
Laguna Titicaca	Sediment cores	27,500 cal BP–present	16S, 69W, 3800 m asl	Paduano et al. 2003	Pollen, charcoal
Laguna Titicaca	Sediment cores	20,000 BP–present	16S, 69W, 3800 m asl	Rowe et al. 2002	Organic C and N, stable C and N isotopes, biogenic SiO_2
Laguna Titicaca	Sediment cores	31,500 cal BP–present	16S, 69W, 3800 m asl	Tapia et al. 2003	Diatoms
Laguna Tuctua	Sediment cores	11,360 ± 110 BP–present	11°40S, 75°00′W, 4250 m asl	Hansen et al. 1994	Pollen
Laguna Viscachani	Sediment cores	12,000 cal BP–present	16°11′S, 68°07′W, 3740 m asl	Abbott et al. 1997b, 2003	Sediment stratigraphy, lithology, bulk density, C content, biogenic silica, diatoms, $\delta^{18}O$
Laguna Yaguarcocha	Sediment cores	11,700 BP–present	0.38°N, 78.08W, 2201 m asl	Colinvaux et al. 1988; Weng et al. 2004	Pollen
Nazca-Palpa region	Sediment	45,000 BP–present	~14.5°S, 75°W	Eitel et al. 2004	Primarily desert loess
Nevado Huascaran	Ice cores	10,000 BP–present	9°06′41″S, 77°36′53″W, 6048 m asl	Thompson et al. 1995	Insoluble dust, $\delta^{18}O$, NO_3^-, pollen
Nevado Illimani	Ice core	18,000 BP–present	16°37′S, 67°46′W, 6350 m asl	Ramirez et al. 2003	Δd, $\delta^{18}O$, dust
Peruvian coast	Archaeofauna	13,000 cal BP–present	Various	Sandweiss 2003; Sandweiss et al. 2001	Faunal/mollusc assemblages
Quebrada los Burros	Archaeological sediments	8980 cal BP–3380 cal BP	18°1′S, 70°50′W, 150 m asl	Fontugne et al. 1999	Sediment stratigraphy
Quelcaya Ice Cap	Ice core	500 AD–present	13.93°S, 70.83°W, 5670 m asl	Thompson et al. 1985	Insoluble dust, $\delta^{18}O$

Table 1 continued

Location	Type of archive	Timespan[a]	Coordinates	Reference	Proxies
Quelcaya, Huascaran, Sajama	Ice cores	25,000 BP–present	various (see above)	Thompson et al. 2000, 2003	Insoluble dust, $\delta^{18}O$, NO_3^-
Sajama Ice Cap	Ice cores	25,000 BP–present	18°06′S, 68°58′W, 6542 m asl	Thompson et al. 1998	Insoluble dust, $\delta^{18}O$, NO_3^-
Seafloor west of Lima	Sediment cores	20,000 BP–present	12°03′S, 77°39.8′W, 184 m bsl	Rein et al. 2005	Chlorins, alkenones, photospectrometry
Valparaiso Basin	Marine sediment core	13,300 BP–present	32°45.00S, 72°02.00W, 2545 m bsl	Marchant et al. 1999	Foraminifera

[a] Radiocarbon years, unless otherwise noted

traditional human–environment interactions in the Andes (Brush 1977, 1982; Mitchell and Guillet 1994; Onuki 1982) as well as linking them to research on human occupation of high-altitude environments generally (Brush 1976; Guillet 1983; Winterhalder and Thomas 1978).

Focus on subsistence should not, however, be equated with attention only to foraging societies. The ways that complex societies in the central Andes adapted to and exploited the particular ecology of the region elicits comment throughout the region and across time periods (Covey 2006; Druss 1987; Shimada 1987, 2000; Silverman 2002; Stanish 2003). As I discuss below, this includes strategies for accessing a variety of ecological zones, construction of subsistence-related infrastructure, risk management, and ritual behavior. Particularly characteristic of archaeological interest in all of these aspects has been attention to diachronic change in central Andean environments.

Paleoenvironments

As environmental factors were increasingly seen as significant cultural influences, diachronic changes in central Andean environments became a concern as well. Archaeological interest in Andean paleoenvironments has resulted in a variety of collaborations with paleoclimatologists; shared interests have led to the identification and exploration of a wide variety of proxy indicators of temperature and precipitation. I briefly explore the broad variety of data available, their geographic and temporal distribution, and the broad climatic patterns they suggest (see Table 1 for details and Fig. 1 for geographic coverage).

Paleoenvironmental archives for the Holocene period in the Andes (c. 11,500 cal BP–present) are recovered primarily in three forms: sediment cores (primarily from lakebed contexts [e.g., Abbott et al. 1997a; Weng et al. 2006] but also marine records [e.g., Rein et al. 2005]), glacial ice cores (e.g., Ramirez et al. 2003; Thompson et al. 1995), and biota in archaeological contexts (e.g., Reitz 2001; Sandweiss 2003; Smith 1980; Stahl 1991). Landforms—e.g., moraines evidencing timing of glacial advance and retreat, movement of dune fields marking periods of aridity, flood deposits testifying to storm magnitude and frequency—also are used to provide paleoclimate assessments (e.g., Farber et al. 2005; Seltzer 1990; Seltzer and Rodbell 2005).

From these archives a variety of proxy data are recovered and used to infer past precipitation, temperature, and/or vegetation. Proxies share some basic characteristics: annual, seasonal, or at least regular deposition that reflects in some way changing local environmental conditions, and datability (for thorough discussion of the use of paleoenvironmental proxies see Lowe and Walker 1997; Negendank 2004; Roberts 1998). Precision and accuracy of the resulting reconstructed patterns of climate change over time vary according to proxy and core. Catchment area reflected in a given proxy, interpretation of the relationship of a proxy to the climatic variables in question, and chronological resolution all vary from archive to archive (and assessment of these parameters is often contested in the literature—e.g., Grosjean et al. 2003). The proxies most commonly used in central Andean paleoclimatic archives are pollen, $\delta^{18}O$, and sediment stratigraphy in sediment cores, and dust, $\delta^{18}O$, and pollen in ice cores. In the case of sediment cores, these yield information on regional vegetation, water balance, and basin erosive regimes, respectively; for ice cores, they provide information on regional aridity, water balance, and regional vegetation.

Creative recognition and querying of new archives is adding to the paleoenvironmental picture (e.g., use of pack-rat middens [Betancourt et al. 2000] and marine mollusk remain as indicators of El Niño/Southern Oscillation (ENSO) history [Carré et al. 2005; Rollins et al. 1986; Sandweiss et al. 2001]). Dendrochronology has been little used in the central Andes, as data are only sparsely available as in South America, almost exclusively in high-latitude, temperate regions where species with clear annual rings are common. Tropical trees have been little used in dendrochronology generally because of a lack of distinct annual rings in those species. However, the successful construction of a nearly 600-year dendrochronological sequence using the low-latitude, high-altitude *Polylepis tarapacana* in Bolivia suggests the problem may be solvable, and there is evidence that tropical tree species may contain proxy records of El Niño events (Boninsegna 2002, p. 12; Chepstow-Lusty et al. 1998, pp. 167–168; Rodríguez et al. 1993).

Data have been generated, primarily in the last two decades, from an increasing number of paleoenvironmental archives in the Andes and are now fairly widely distributed, although they remain much more common in the south-central Andes than elsewhere (see Fig. 1). The uneven spatial distribution of paleoenvironmental archives often makes the direct inference of environmental history for a given archaeological site or area difficult, but the broad patterns are increasingly clear.

Various climatic indicators suggest the establishment of relatively modern climatic conditions in the central Andes by the later mid-Holocene. Multiple proxies from sediment cores from Lake Titicaca suggest a generally wetter climate from approximately 4500 BP (e.g., Baker et al. 2001; Cross et al. 2001; Paduano et al. 2003). This trend is interrupted by several “pronounced century-scale droughts,” however, and the timing of the climate shifts documented in the Titicaca and other south-central Andean records is not uniform (see Abbott et al. 2003). In terms of broad patterns, however, pollen data in sediment cores from the Junín area similarly suggest wetter conditions beginning around 5000 BP (Hansen et al. 1994); glacial ice cores from Nevado Huascarán (Thompson et al. 1995) basically agree. Thompson and colleagues (1995, 2000) interpret the Huascarán record to indicate warming following the onset of the Holocene, with conditions warmest between 8400 and 5200 BP, then gradually cooling through the Little Ice Age (beginning 500 BP). Their data, they suggest, are consistent with Markgraf’s (1989) estimate that modern vegetation patterns date to approximately 3000 BP.

Temporal coverage of relevant paleoenvironmental archives in the Andean region goes back to the Late Pleistocene. Resolution ranges from quite coarse—a handful of radiocarbon dates anchoring linearly interpolated time/depth curves—to remarkably fine—large numbers of radiocarbon dates or annually deposited, countable layers.

The archaeological impact of this body of paleoclimatic data is diverse. On the coast, attention was drawn early on to the effects of Holocene changes in sea level on coastal resources (Richardson 1981). Changes in water temperature and consequently marine faunal resources also have received considerable attention (e.g., Reitz 2001; Reitz and Sandweiss 2001; Sandweiss 2003), both for their value as paleoenvironmental indicators per se and for what they indicate about subsistence possibilities for inhabitants of the Peruvian coast. Extensive literature addresses the antiquity and variability of the El Niño phenomenon (e.g., Fontugne et al. 1999; Moy et al. 2002; Sandweiss et al. 1996, 2001), focused in particular on the cultural consequences of El Niño events (discussed in detail below).

In the highlands, several types of changes have been identified as important to human occupation of the region. Most basic among these is the deglaciation associated with the Pleistocene-Holocene transition (Aldenderfer 1999; Dollfus and Lavallee 1973; Grosjean et al. 2007; Lynch 1990), but archaeologists also are interested in long-term fluctuations in temperature and precipitation during the Holocene (Baied and Wheeler 1993; Binford et al. 1997; Grosjean et al. 2007; Marchant et al. 2004; Nuñez et al. 2001; Rick 1983), mindful of the sensitive linkage between temperature and precipitation on the one hand and vertically distributed ecological zones on the other. There also has been significant archaeological attention paid to the effect of the Younger Dryas in the Andes and its implications for the region's human inhabitants (e.g., Grosjean and Nuñez 1994; Nuñez et al. 2001, 2002). The effects of climate-driven geographic shifts in local ecologies have important implications for the subsistence potentials of areas exploited in prehistory (Branch et al. 2007; Cardich 1985; Seltzer and Hastorf 1990) and may have prompted engineering solutions as well as shifts in settlement patterns, population sizes and densities, and cultural complexity.

El Niño

A related focus is dramatic environmental variation, exemplified by the El Niño/Southern Oscillation (ENSO) phenomenon. Research has attempted to describe the range of variability of ENSO events, identify them in prehistory, characterize their impacts on both Andean ecology and human civilizations, and address long-term changes in the patterns of ENSO occurrence. Van Buren (2001) provides an excellent critical overview of this research.

El Ñino is a quasiperiodic influx of warm waters into the coastal areas off of Peru. Primary effects—varying depending on the severity of the event—are die-offs of marine life accustomed to more nutrient-rich cold waters, and torrential rains on the normally arid coast. ENSO events also have been linked to drought in the highlands of the south-central Andes as well as the Amazonian region (Markgraf 2001). A substantial modern literature focuses on describing the events of recent and well-documented El Niño events (Caviedes 1984a, b; Glynn 1988; Jaksic 2001; Nials et al. 1979). In addition, archival research demonstrates that the phenomenon was recognized in the colonial period and that event severity has varied dramatically over the last four centuries (Garcia-Herrera et al. 2008; Hocquenghem and Ortlieb 1992; Huertas Vallejos 1987, 2001; Macharé and Ortlieb 1993; Ortlieb 2000; Ortlieb and Macharé 1993; Quinn et al. 1987).

The ENSO record for deeper time consists of multiple proxies from various locations that indicate a relatively low frequency of El Niño events during the mid-Holocene, followed by an upturn in frequency that is variously placed around 7000 BP (Moy et al. 2002; Rodbell et al. 1999) or 5800 BP (Sandweiss et al. 2001). A further increase in El Niño events—to modern frequency—apparently occurred at approximately 3000 BP; Sandweiss (2003, p. 38) argues that modern conditions accompanied this change in ENSO regime on the coast.

The argument for the mid-Holocene onset of the modern ENSO regime has its critics (DeVries et al. 1997), but other paleo-ENSO records now largely corroborate the suggested pattern. A 38,000-year record of sediment stratigraphy recording El Niño-induced flooding at Quebrada Tacahuay on the south coast of Peru, for instance, shows an increase in El Niño frequency beginning about 5300 BP (Keefer et al. 2003). Similarly, Rein and colleagues (2005) interpret a marine core taken off the coast of Lima to indicate the onset of the modern strong El Niño pattern between 4000 and 5000 BP. They also describe a mid-Holocene hiatus from roughly 8000 to 5000 BP. Rodbell et al. (1999), using data from a lake core from highland Ecuador, argue for a 7000 BP onset of El Niño and a 5000 BP increase to modern frequency.

The beginning of a modern El Niño pattern at 3000 cal BC would have meant that subsequent to this date pre-Columbian populations experienced ENSO events on a quasiperiodic basis, roughly every 7–10 years. The severity of such events, as both historic and prehistoric records emphasize, would have varied unpredictably. The specific identification and dating of severe events and their effects on the region's inhabitants have been the subject of substantial debate. This literature may be situated in the context of broader discussions about the significance of environmental risk in the central Andes and the linkages between environmental and cultural change. I turn to these two themes below.

Hazards and disasters

Archaeological attention to paleoclimate has been not just to broad patterns—e.g., deglaciation, ENSO onset, shifts in precipitation—but also to dramatic events. Grounded in paleoenvironmental (e.g., Piovano et al. 2006) and historical (e.g., Ames Marquez and Francou 1995; Huertas Vallejos 1987, 2001) study, this research has begun to engage with the studies of contemporary natural disasters, which have drawn a conceptual distinction between hazard—chance of relatively abrupt environmental event—and disaster—occurrence of a specific environmental event that has catastrophic consequences for a human population (Oliver-Smith and Hoffman 1999; Van Buren 2001). Attention is on the ways that human activity (e.g., location, infrastructure, social organization) affects the potential conversion of an environmental change into a natural disaster (Bode 1989; Carey 2005; Oliver-Smith 1986).

In the archaeological literature, various catastrophic events such as earthquakes, tsunamis, and debris flows (often linked with one another and with El Niño events) are being studied. Specifically, attention to El Niño consists of use of archaeological deposits as paleoenvironmental proxies (Sandweiss 2003), identification of ENSO-related deposits in archaeological sites (Craig and Shimada 1986; Fontugne et al. 1999; Grodzicki 1990; Keefer et al. 1998, 2003; Uceda C. and Canziani Amico 1993), and interpretation of the relationship between prehistoric ENSO events and sociopolitical changes (Chapdelaine 2000; Magilligan and Goldstein 2001; Moore 1991; Reycraft 2000; Sandweiss et al. 2001, 2007).

Earthquakes remain difficult to identify with confidence in the archaeological record (Ambraseys 2006), but the high level of seismic activity in western South America makes their occurrence in prehistory a virtual certainty. Simple extrapolation from historic recurrence intervals suggests their likely regularity in Andean prehistory (Comte and Pardo 1991; Degg and Chester 2005; Dorbath et al. 1990); Bandelier (1906) anticipated this research by nearly a century. In a handful of contexts, archaeologists and/or geologists believe they have identified evidence of earthquake damage (Kovach 2004; Rick 2008; Sandweiss et al. 2009; Shimada 1981). The design of Inca architecture, in particular, has been analyzed to learn whether it is engineered to withstand earthquakes (e.g., Cuadra et al. 2008).

The ancillary effects of earthquakes in the central Andes can be quite severe, including tsunamis, debris flows, and landslides. Historical records suggest the relative frequency of tsunamis (Berninghausen 1962; Degg and Chester 2005; Kulikov et al. 2005; Lockridge 1985), as well as the frequency and severity of debris flows (Ames Marquez and Francou 1995; Carey 2005; Cluff 1971; Plafker and Ericksen 1978; Plafker et al. 1971). Like earthquakes, tsunamis may also have been identified in the archaeological record (Bird 1987). Debris flows—probably linked to ENSO rains and possibly earthquakes—have been identified with more confidence (Brooks et al. 2005; Grosjean et al. 1997; Keefer et al. 2003; Reycraft 2000; Satterlee et al. 2001). The archaeological visibility of interrelated earthquakes, El Niño events, and debris flows has been explored as well (Fontugne et al. 1999; Keefer and Moseley 2004; Keefer et al. 2003).

Volcanic activity is common in the central Andes (Degg and Chester 2005; Thouret et al. 2002b), and there is a long history of documented eruptions, dating back to the AD 1600 eruption of Huaynaputina in southern Peru (de Silva et al. 2000; Thouret et al. 1999, 2002a). Positive identification of specific volcanic events in prehistory is rare in the central Andes, but nonetheless volcanic activity has been suggested as an influential factor in cultural developments in Ecuador (Hall and Mothes 2008; Zeidler 2008; Zeidler and Isaacson 2003), and its memorialization in indigenous myths has been explored (Masse and Masse 2007).

Much of the attention on prehistoric disasters has focused on damage to infrastructure, seen as more likely to prompt long-term change than simple loss of life. Much of this literature consists of dispute about the vulnerability of pre-Columbian populations to environmental variability, with charges of environmental and cultural determinism the currency of debate (Erickson 1999; Kolata 2000; Moseley 1997).

Environmentally correlated florescence and collapse

Attention to climatic change in general and catastrophic events in particular has often been associated with arguments linking such shifts to the disappearance or dramatic alteration of cultural patterns—often characterized as “cultural collapse” (Binford et al. 1997; Brenner et al. 2001; Ortloff and Kolata 1993; Paulsen 1976; Shimada et al. 1991). Beginning in the 1970 s, archaeologists working on the coast of Peru began to consider prehistoric El Niño events as potential cultural influences (Osborn 1977; Parsons 1970; Paulsen 1976). With greater understanding of the history of the ENSO phenomenon, that attention has increased, and paleoenvironmental indicators of warming of marine waters, catastrophic flooding on the coast, and drought in the altiplano of the south-central Andes have been correlated with the florescence and collapse of multiple Andean polities, with varying degrees of subtlety.

Debate continues over the strength of the chronological linkages between ENSO events and cultural change, the exact nature of the posited collapses, and the intervening social processes that connect environmental perturbation to cultural change (Erickson 1999; Kolata 2000; Moseley 1997; Williams 2002). Simply noting rough chronological correspondence, many have argued, is not sufficient—rather, links between environmental phenomena and cultural change need to be clearly articulated. Van Buren's (2001) synthesis of the literature on El Niño notes critically that the phenomenon has been used as an explanation for a wide variety of different cultural developments and risks degeneration into a *deus ex machina*. As she points out, similar criticism might also be leveled at arguments involving other catastrophic events. If precise linkages remain to be explained, however, chronological correlations between climatic perturbations and cultural change are becoming increasingly well documented (deMenocal 2001; Sandweiss et al. 1999, 2001, 2007; Wells and Noller 1999), and explicit recognition that the linkages need better articulation has become more common (e.g., Andrus et al. 2008; Coombes and Barber 2005; Marchant et al. 2004).

One of the foci of these debates is the growth and decline of Tiwanaku in the Titicaca Basin. At Tiwanaku, local paleoenvironmental data (drawn from a variety of proxies, primarily in Lake Titicaca sediments) are much more abundant than for most sites in the central Andes; nevertheless, consensus regarding the interpretation of chronological correlations of cultural and environmental changes is elusive. General correlation of prolonged drought (marked primarily by a lowstand of Lake Titicaca [see Abbott et al. 1997a, inter alia] and reduced precipitation recorded in the Quelccaya ice cap [see Thompson et al. 1985, inter alia]) with Tiwanaku's decline in the 12th century AD is broadly accepted. Arguments attributing Tiwanaku's collapse to climate-linked agrarian failure (e.g., Binford et al. 1997; Brenner et al. 2001; Kolata and Ortloff 1996; Ortloff and Kolata 1993), however, have been met by critics who counter that chronological correlation should not be equated with environmental causation (e.g., Erickson 1999; Erickson 2000), that the dating of relevant archaeological features (i.e., raised-field complexes) is not precise enough to allow causal inference (Erickson 1999), and that better-articulated models of social processes linked to agricultural production are necessary (Graffam 1992; Janusek 2005). Stanish (2003), in his summary of Lake Titicaca paleoecology, makes the point that the paleoclimatic models do not always agree exactly in their chronologies; he concludes that the data quality limits, for the present, the possibility of integrating paleoclimatic reconstruction into specific archaeological explanation. In contrast, Kolata and colleagues (Kolata 2000; Kolata et al. 2000) argue that the parameters of Tiwanaku's environment were such that, even in the absence of precise chronological correlation or the articulation of specific mechanisms relating climatic factors to sociopolitical change, it remains reasonable to infer a general link between drought and collapse.

One area where links between environmental and sociopolitical change have been more thoroughly elucidated is in environmental damage to irrigation infrastructure, though the specific cultural consequences of that damage often remain less clearly understood. Given the sensitivity of canal systems to changes in slope, the effect of erosive or tectonic activity on the often elaborate irrigation systems of coastal valleys has been a particular focus. Pioneering arguments by Moseley and colleagues (Browman 1983; Clement and Moseley 1991; Moseley 1983; Moseley et al. 1983) ascribed the greater extent of prehistoric cultivation relative to modern agriculture primarily to tectonic uplift and channel incision that stranded canal intakes and left previously cultivated swaths of desert unirrigable. Resulting dispute (Kus 1984; Ortloff et al. 1983; Pozorski and Pozorski 1982) centered on interpretation of canal infrastructure and evidence for uplift (Wells and Noller 1999). Later work has focused on the physical damage to irrigation systems associated with strong El Niño events (Browman 1983; Reycraft 2000; Satterlee et al. 2001; Williams 2002). Moore, studying Chimu response in the Casma Valley to a major El Niño event, was able to highlight the fact that the consequences of El Niños need not be construed as exclusively negative. Although El Niño events require adaptive responses, at the same time they open new niches for exploitation; in the Casma case, flooded land became amenable to raised-field cultivation (Moore 1988, 1991). Similar emphasis on reconfiguration rather than collapse characterizes other recent ENSO-related work (Chapdelaine 2000; Williams 2002; Zaro and Umire Álvarez 2005).

These detailed studies of particular local trajectories that involve El Niño events contrast with broad-brush portraits that simply highlight the chronological association of environmental perturbations (ENSO or other) with cultural change, or assert that the co-occurrence of human occupation and a variable environment in itself explains cultural trajectories in the Andes. Although invocations of changes in ENSO regime or citations of particular events are plausible as cultural influences, explanations of process are rare, due at least in part to the difficulty of elucidating such process archaeologically. Tantalizing examples point to the cultural significance of particular ENSO events in prehistory, as in the case of the several sacrificed prisoners found in El Niño alluvial deposits at Huaca de la Luna in the Moche Valley (Bourget 2001). More speculative and generalized treatments are much more common, such as Burger's (1988) and Onuki's (1995) suggestions that the decline of Peruvian coastal centers in the first millennium BC might be ENSO-related. Other researchers have suggested more broadly inclusive scenarios in which a variety of abrupt environmental changes are linked to cultural change (Moseley 1999, 2002; Sandweiss et al. 2009). Jennings (2008) has recently suggested that environmental disasters in central Andean prehistory would have had ideological as well as subsistence consequences, undermining the credibility of religious authority (this echoes Burger's [1993] suggestion that the spread of Chavín-related ideology in the first millennium BC may have been related to disaster-induced ideological stress).

In addition to the impact of catastrophic events, archaeologists have highlighted two correlations between longer-term climatic shifts and cultural change, both collapse and florescence. This work has been primarily grounded in chronological correlation of cultural patterns and paleoclimatic data, whether drought (Binford et al. 1997; Shimada et al. 1991), warming (Aldenderfer 1999; Cardich 1985), or variability itself (Kornbacher 1999; Moseley 1997, 1999; Sandweiss et al. 2001).

Modified environments

Studies of Andean environments as modified by human activity have burgeoned in recent years, in both coastal and highland research, including studies of both unintentional human impact and deliberate human modification. These generally consist of reconstructions of unintentional environmental degradation resulting from prehistoric activity, on the one hand, and studies of intentional anthropogenic modification of Andean landscapes, generally to enhance subsistence potential, on the other.

Suggestions that distributions of vegetation in the Andes reflect a legacy of human activity rather than limitations of temperature, precipitation, and altitude have come primarily from geographers rather than archaeologists. Ellenberg (1979) provocatively argued that distributions of *Polylepis* trees in the high Andes were anthropogenic; others have suggested the possibility of human effects on vegetative distributions more generally (Budowski 1968; Seibert 1983; Zimmerer and Langstroth 1993). Ellenberg's contention has recently been raised again (Baied 1999; Kessler 2002) and explored (Sarmiento 2000; Sarmiento and Frolich 2002). Chief among these is anthropogenic burning: both pastoralism and early agriculture were probably associated with regular application of fire to the landscape. Pastoralists—or for that matter their hunter predecessors—may burn grasslands to encourage the growth of tender forage; for agriculturalists in the central Andes, burns are a means of clearing land for cultivation. While the bunchgrasses that characterize puna vegetation (known generically as *ichu*, encompassing *Stipa ichu* and *Festuca* spp.) are burn tolerant, *Polylepis* are particularly vulnerable to repeated application of fire (Kessler 2002; Laegaard 1992).

Archaeological treatments of human impacts on vegetation in the Andes tend to be more local in scope and more grounded in specific evidence (e.g., Chepstow-Lusty et al. 1996). Johannessen and Hastorf (1990) and Erickson (1992) argue that the record reflects conscious processes of management rather than unintentional impact. Similarly, Chepstow-Lusty and Winfield (2000) use paleobotanical data to argue for the modern relevance of reconstructions of prehispanic resource use. Fauna also are of interest to archaeologists, including estimates of human impacts on fauna (Rick 1980; Stahl 1996) and recently the impact of human-managed fauna on environments (Chepstow-Lusty et al. 2007).

In addition to impacts on flora and fauna, whether intentional or incidental, archaeologists have documented other environmental impacts, though this literature is still relatively small. These include salinization resulting from irrigation (Armillas 1961; Ford and Willey 1949; Willey 1953, p. 16) and, later in prehistory, the accumulation of pollution from smelting (Abbott and Wolfe 2003; Cooke et al. 2008, 2009). Change in vegetation and increased erosion likely accompanied anthropogenic burns beginning by at least the mid-Holocene. Increased charcoal inputs beginning ~9000 BP in sediment cores from various Andean locations, however, have been the subject of some debate; the increased frequency of charcoal may be associated either with early Holocene warming or human activity (Hansen et al. 1994; Weng et al. 2004, 2006). Although there is general agreement that a change in fire regime occurred at that time, the change may not necessarily be related to human activity (see Paduano et al. 2003). Where increased charcoal flux has been accompanied by increasing frequency of weedy species (e.g., *Ambrosia* spp. and Chenopodiaceae/Amaranthaceae; see Chepstow-Lusty et al. 2003; Weng et al. 2006), generally closer to 5000 BP, the argument for landscape change resulting from anthropogenic burning is stronger, though not resolved.

Deliberate environmental modification includes both attempts to enhance agricultural/subsistence potential directly and engineering efforts to manage risk or alter the landscape for ideological reasons. Prehispanic engineering—particularly terracing and raised-field agriculture—has generated a substantial literature in archaeology and geography. Denevan's (2001) synthesis and Lentz' edited volume (2000) are the most comprehensive geographically and represent the most complete catalogs of landscapes modified for agricultural purposes. As elsewhere in the world, increasing availability and use of remotely sensed imagery continues to multiply the record of prehistoric agricultural features in general, as it has since the Shippee-Johnson expedition introduced aerial photography to Peruvian archaeology (Shippee 1932a, b) and made Kosok's (1965) pioneering work possible.

More local studies have investigated the longevity of terraces (Branch et al. 2007; Williams et al. 2005), their effects on erosive regimes (Inbar and Llerena 2000), and the mechanisms by which they enhance agricultural potential (Dick et al. 1994; Goodman-Elgar 2008; Kemp et al. 2006). Raised-field agriculture, particularly in the Titicaca Basin, became a significant research focus in the 1990s (Carney et al. 1993; Erickson 1992, 2000; Graffam 1992; Kolata 1991; Stanish 1994). Debate continues over whether raised-field systems, much like canal systems on the coast, represent top-down, elite-directed or bottom-up, not centrally organized construction efforts (Bandy 2005; Erickson 2000; Janusek and Kolata 2004).

Irrigation infrastructure is the subject of even more archaeological attention. Canal systems, dating back to the mid-Holocene, have been documented in coastal Peru for decades (Dillehay et al. 2005; Eling 1986; Farrington 1980; Hayashida 2006; Kosok 1965; Moseley and Deeds 1982; Netherly 1984; Park 1983; Schreiber and Lancho Rojas 2003). Sunken field systems (Moseley 1969; Ojeda Enriquez 1987; Parsons 1968; Parsons and Psuty 1975; Rowe 1969; Smith 1979), water-table farming (West 1979), capture of moisture from fog drip (Benfer et al. 1987), and floodwater farming (West 1981) also have been recorded. Moreover, as Denevan (1970, 1992, 2001) and others (Denevan et al. 1987; Parsons 1985; Schjellerup 1992) have emphasized that raised-field agriculture in the central Andes is not confined to the Titicaca Basin. Even on the central Andean coast, generally associated more with canal irrigation and sunken fields, Pozorski et al. (1983) and Moore (1988) identified raised fields in the Casma Valley, and raised fields have been well documented in Ecuador's Guayas Basin (Denevan et al. 1987; McEwan and Delgado-Espinoza 2008; Parsons 1969).

These types of agricultural modifications had a less visible counterpart, as agricultural practices leave soil signatures in addition to built features. Identification and analysis of these anthroposols has been a focus of research on prehistoric subsistence and environmental impact, often as the subject of collaboration between archaeologists and soil scientists (Dick et al. 1994; Goodman-Elgar 2008; Hesse and Baade 2009; Kemp et al. 2006; Nordt et al. 2004; Sandor and Eash 1995). These efforts have demonstrated the long-term effects of agricultural practices and have suggested that soils were consciously managed (e.g., by addition of soil amendments and control of erosion).

Prehispanic landscape engineering also included efforts that were not strictly agricultural. At high altitudes in the south-central Andes, Flores Ochoa (1987) documented extensive systems of artificial reservoirs known as *qochas* that were used primarily for water storage, as agricultural fields, and as pasture. Analogously, Lane (2006, 2009) has documented extensive damming of puna streams to create *bofedales* (wetlands) and ponds by late prehistoric agropastoralists in the Cordillera Negra. Given the importance of herding in Andean prehistory, many more such features likely will be documented as archaeologists begin to look for them more systematically. Sophisticated hydrologic engineering and associated labor-intensive systems are more common in the Inca period (e.g., Fairley 2003; Wright et al. 2006).

Risk management also was clearly a prehistoric concern in the Andes, though one little investigated to date. Both Burger (2003) and Brooks et al. (2005) describe massive construction features designed to protect sites in coastal valleys from debris flows that could descend neighboring *quebradas* during severe ENSO events. Silverman (2002) reports two similar features in the Ingenio Valley of the Río Grande de Nazca drainage. Similarly, Knapp (1982) argues that the coastal sunken-field systems were in fact flood-control features. Just how common such features were on the coast is still unknown; Reycraft (2000, p. 118), for instance, explicitly mentions their absence in Chiribaya settlements. In the central Andean highlands examples are fewer, but the builders of Chavín de Huántar partially canalized the two rivers flanking the site, partly as a flood control measure (Contreras 2007, 2008; Rick 2005).

A subset of research on modified environments has considered the symbolic and ideological content of Andean landscapes, with particular attention to cases where landscapes or landscape features have been physically altered for ideological as well as practical reasons.

Sacred landscapes

Strong ethnohistoric and ethnographic evidence points to the ideological and ritual significance of landscape features for native Andean peoples. On the basis of analogy, or in the case of later prehistory, on the basis of direct investigation of material correlates of ethnohistoric documentation, central Andean archaeologists have pursued the reconstruction and interpretation of sacred Andean landscapes.

A significant body of ethnohistoric documentation (e.g., the Huarochirí Manuscript [Salomon and Urioste 1991] and Albornoz' *Instrucción* [Duviols 1984]) testifies to Inca and other Andean conceptions of certain landscape features (springs, rock outcrops, caves, etc.) as sacred elements (*huacas*) and to the divine significance attached to mountain peaks (*apus*). These were conceptually tied together into entire sacred landscapes (Silverman 2004; van de Guchte 1999).

Several archaeological projects have attempted to identify such features: in some cases those directly described in ethnohistoric documents (Bauer 1998; Bauer and Stanish 2000; Meddens et al. 2008; Reinhard 1985b; Reinhard and Ceruti 2005; Zuidema 1962) and in others by analogy to ethnohistoric and ethnographic accounts (Glowacki and Malpass 2003; Jennings 2003; Moore 2004, 2005; Reinhard 1985a; Schreiber 2005). Early interest in the symbolic significance attributed to the landscape by the Inca (Reinhard 1985a, b; Zuidema 1962) in some ways foreshadowed interest in symbolic and phenomenological approaches to landscape in archaeology generally (Ashmore and Knapp 1999; Thomas 2001; Tilley 1994). The combination of Andean ecology and ethnohistory suggests a very real need, in Andean archaeology, for consideration of both ecosystemic and symbolic readings of environments.

As environmental settings, landscapes have been of interest for their productive capacities and constraints, predictability and risk, and amenability to anthropogenic modification. As sacred settings, they have been the focus of attention with respect to ritual practices, hypothesized indigenous orderings and prioritizings of landscape features, and productions and reproductions of the social order. Much of this has been based on ethnohistoric analogy to comparatively well-documented Inca sacred landscapes (Glowacki and Malpass 2003; Gose 1993; Reinhard 1985b). As Moore (2005, p. 218) emphasizes, such material must be used circumspectly (to cavalierly use the Inca as representative of *lo andino*—that is, Andean beliefs and practices generally—ignores intra-Andean variability in both space and time), but it is nevertheless invaluable.

Most common among these analogies is the projection into the pre-Incaic past of the concept of the huaca. The term is understood from Spanish colonial attempts to extirpate indigenous religious practice to encompass sacred features of various sorts, both natural and manmade (Duviols 1984; see also Glowacki and Malpass 2003; Staller 2008). Ramírez (1996, chap. 5) discusses the issue in detail, concluding on the basis of colonial period legal documentation that the term was used (and misused) by the Spanish to gloss a wide array of native beliefs.

Huacas were generally treated as shrines, whether in their original state, modified, or incorporated into built space. The result, Silverman (2004, p. 5) writes, was that the Andean world was "animistic … populated with supernatural beings, sacralized mountains, lakes, springs, irrigation canals, boulders and caves, numina-lodging objects, and anthropomorphized forces of nature." Huacas were, in other words, omnipresent. With this importance and omnipresence in mind, Andean archaeologists have extensively used the concept of the huaca to explain pre-Inca material remains and spatial organization (e.g., Farrington 1992; Glowacki and Malpass 2003; Schreiber 2005).

More generalized sacred elements also were recognized by both the Inca and earlier Andean peoples. Water and mountain peaks provide two well-documented examples. Gose (1993, p. 482) describes the ritual importance of water as an almost obsessive concern, even in the highlands, where its practical importance was not so transcendent as on the coast. While irrigation agriculture provided an obvious and immediate rationale for concern about adequate provision of water on the coast, similar concern is apparent in the highlands in spite of the less apparent worry over supply. Elaborate ritual manipulation of water is well documented in sites spanning the geography and chronology of the central Andes, e.g., Wari (Isbell and McEwan 1991), Tiwanaku (Kolata 1993), Chavín (Lumbreras and Chacho Lieataer 1976), Kuntur Wasi (Onuki 1995), and many Inca sites (see Niederer 1990; Wright et al. 2006). The Cumbemayo canal, carved through bedrock outside modern-day Cajamarca, is perhaps the most impressive example (Petersen 1985).

Mountain peaks, ever present in the central Andes, also were cosmologically significant and were seen as potent deities and sources of water (Castro and Aldunate 2003; Reinhard 1985a). As such, they served as significant foci of ritual attention. Reinhard has documented this extensively for the Inca (e.g., Reinhard 1985b; Reinhard and Ceruti 2005); he and others have argued that such beliefs were common to earlier Andean peoples as well (Reinhard 1985a; Williams and Nash 2006). Benson (2001, p. 13) notes that mountains are still deified and sacred in the Andes today.

Glowacki and Malpass (2003) argue that these individual features were knitted into a coherent whole; drawing on analogies to the Inca, they describe (p. 443) the central Andes for the Wari as comprising a vast sacred landscape of "natural phenomena, human construction, and associated objects." As Glowacki and Malpass discuss, a variety of ethnohistoric evidence testifies to the Inca understanding the Andean landscape in such terms. That descriptions of the cognized landscape had material manifestation as well is clear from the archaeology of the Inca heartland, where, for instance, shrines of the system of *ceque* lines radiating out from Cuzco have been identified (Bauer 1998; Zuidema 1962). One key implication of this body of work that identifies the landscape itself as sacred is that landscape modification might have symbolic and ritual ends as much as practical ones (Goodman-Elgar 2009).

Moving forward: Insights from the central Andes

Archaeology is uniquely situated to address long-term human–environment interactions (see Costanza et al. 2007; Fisher and Feinman 2005; Hardesty 2007; Hayashida 2005; Kirch 2005; van der Leeuw and Redman 2002). That potential springs from both archaeology's long-term perspective and its long history of ties to the natural sciences. Living up to that potential will require, however, the development of a position that draws on both environment and landscape approaches.

Central Andean archaeology, with its long and intellectually diverse history of interest in human–environment interactions, has much to contribute. Three lessons stand out from the Andes: (1) settings are dynamic, and dynamism itself matters, (2) anthropogenic modification is pervasive, and (3) settings are important as both environment and landscape.

Dynamic settings

Paleoclimatic variability within the Holocene is usually understood because of the temporal resolution of the relevant proxies and the general perception of the processes involved as incremental, as occurring on a geologic timescale of centuries to millennia. As data resolution has improved and shorter-term processes (e.g., ENSO) have become better documented, decadal and even annual variability has become a more common topic of discussion (Moseley 1999; Wells and Noller 1999). The resolution of paleoclimatic data has interpretive repercussions; as Moseley (1997; Moseley et al. 1981) has argued, the frequency and tempo of environmental change, since it conditions human perceptions of and reactions to such change, is of keen archaeological relevance.

In addition to identifying particular catastrophic events, whether ENSO-related or tectonic, recent work has highlighted dynamism as endemic to many Andean environments (Dillehay and Kolata 2004; Huckleberry and Billman 2003; Wells and Noller 1999). Erickson (1999) and Van Buren (2001) link this shift in perspective to growing archaeological awareness of the emergence of the “New Ecology” (Scoones 1999; Zimmerer 1994) and its de-emphasis of ecological equilibria.

Such dynamism has important implications for archaeological approaches to sociopolitical change. A growing array of projects has recently attempted to examine changing central Andean polities in their dynamic environmental contexts (e.g., Dillehay and Kolata 2004; Dillehay et al. 2004; Huckleberry and Billman 2003; Manners et al. 2007; Nordt et al. 2004; Reycraft 2000; Rigsby et al. 2003; Wells and Noller 1999; Zaro and Umire Álvarez 2005). These studies build intertwined chronologies of sociopolitical and environmental change, using high-resolution chronologies and detailed catalogs of landscape and architectural/settlement change to approach the processes linking cultural and environmental trajectories. As political ecologists have pointed out (Zimmerer and Bassett 2003), environmental changes are not felt equally across populations and may serve differentially as crisis and opportunity depending on the actors’ sociopolitical locations.

In addition, we may infer that the importance—necessity, even—of ritual was highlighted by the activity of the environmental elements of power that were often the focus of ritual. These were, as discussed above, regarded as sources of sacred power throughout central Andean prehistory, and proximity to such elements has often been used to explain the location of central Andean monumental centers (e.g., Kolata 1993; Reinhard 1985a). Recent Andean history, which includes several natural disasters of frightening scope (e.g., debris flows [Carey 2005; Plafker and Ericksen 1978] and earthquakes [Tavera et al. 2002]), demonstrates that such natural elements are not simply symbolically potent but also powerful—and threatening—in very concrete ways (Rick and Contreras 2006). The link to cosmology is suggested by Benson's emphasis of the practical role of ritual in the central Andes; she (Benson 2001, p. 11) argues that the goal of ritual sacrifice was to establish "contact and contract" with supernatural powers. Lumbreras (1993) suggests that specialist knowledge of environmental phenomena served as a means to power for an emergent theocratic elite—ethnographic research (e.g., Orlove et al. 2000) hints at possible mechanisms—while Bourget (2001, p. 115) proposes that Moche sacrificial practices at Huaca de la Luna were directly linked to El Niño events.

The archaeology of the central Andes thus indicates that dynamic contexts are important not just as generators of taphonomic processes complicating archaeological interpretation of landscapes but also as processes contemporary with pre-Columbian peoples. Archaeological investigation, in other words, should consider dynamic landscapes in two senses: (1) They must be understood as potentially significantly altered even on archaeological timescales and thus demand interpretation and reconstruction if archaeological settings are to be understood, and (2) they must be understood not as long-ago static environments but as settings that were themselves dynamic.

Anthropogenic modification

The ubiquity of anthropogenic landscape modification has become increasingly apparent in recent decades, particularly in the neotropics, where the research program of historical ecology has taken hold in the Americas (Balée 2006; Balée and Erickson 2006). This recognition of a pervasive and substantial human footprint has a central Andean component as well. In the central Andes, as elsewhere in the Americas, recent decades have seen the growth of concern over the length of occupation and degree of landscape modification and the ways that underestimating the anthropogenic footprint may have distorted traditional reconstructions of human–environment interaction (e.g., Denevan 2001; Lentz 2000). The suggestion that marginal environments stimulated extensive human modification—rather than simply forcing behavioral adaptation—is a significant theoretical shift.

In the Americas generally, a significant question is that of the nature of the human–environment interaction in the prehispanic New World (Krech 1999, 2005). The dissolution of the illusions of both the "noble savage" essentially incapable of modifying the environment and the Arcadian indigene living in unchanging harmony with nature has had theoretical consequences. Approaches based on those fallacies have been replaced by others that emphasize environmental plasticity in order to highlight the centrality of indigenous agency (e.g., Erickson 2000; Young 2008), more sophisticated and subtle examinations of environmental influences (e.g., Dillehay and Kolata 2004; Marchant et al. 2004), and nuanced approaches that see humans and their environments as mutually constitutive (e.g., Dillehay et al. 2004; Wells and Noller 1999; Williams 2002).

This diversity of pre-Columbian interactions with the varied array of central Andean environments provides an excellent arena for investigating prehistoric sustainability and resilience. Which approaches were sustainable and why, and what the long-term effects of human practices are remain key subjects for further research. Such research is relevant to both archaeology more broadly and modern policy making, as van der Leeuw and Redman (2002) hope archaeology generally will be. This contribution of archaeology to studies of sustainability has been broadly noted (Fisher and Feinman 2005; Fisher and Thurston 1999; French 2007; Peeples et al. 2006; Redman 2005; Redman and Kinzig 2003; Scarborough 2003) but rarely with reference to central Andean examples. The general relevance of the broad corpus of Andean cases has only begun to be explored (Moseley 1999), and it is noteworthy that there has been little attention paid to the central Andes with respect to the kinds of human-induced environmental catastrophes that have made compelling reading elsewhere (e.g., Diamond 1995; Kirch 1997; Redman 1999; Redman et al. 2004; Spriggs 1997). This may simply reflect a phase of research focused more on defining the parameters of environmental variability and anthropogenic enhancement in a region where both are dramatic, and a focus on phenomena (e.g., El Niño) apparently beyond the reach of prehistoric human influence. A few studies, however—e.g., the evidence for salinization of agricultural fields in the Virú Valley (Ford and Willey 1949; Willey 1953) and Richerson's (1993) investigation of humans as an active element over the long term in the Titicaca Basin ecosystem—suggest that more attention to the interplay of environmental and anthropogenic factors may result in a growing catalog of human-induced environmental problems. As Fisher and Feinman (2005) and Redman (2005) emphasize, recognition of such instances is as much a question of analytic scale as of material evidence. Exploring such questions of lack of resilience, as well as continuing to document remarkable successes, is clearly a necessary focus in the central Andes.

Settings as environments and landscapes

The archaeology of environment and landscape in the central Andes is highlighting the importance of considering setting as multivalent. That is, the literature reviewed here demonstrates that the settings in which prehispanic peoples of the central Andes lived were significant for their occupants in multiple ways, including as resource suites, sources of risk, and ideologically fraught terrains. The rhetorical opposition of environment and landscape, this literature emphasizes, limits our ability to evaluate the significance of settings for past peoples. To approach the importance of prehistoric settings for their inhabitants, archaeologists must recognize that these might simultaneously play multiple roles.

Broad-minded archaeological approaches to landscape and environment recognize this already. The term "landscape archaeology" is a labile one and has already been applied to diverse archaeological approaches (see Preucel and Hodder 1996, pp. 32–33). Ideally, as Anschuetz et al. (2001, p. 159) argue, the term might encompass "the recognition and evaluation of the dynamic, interdependent relationships that people maintain with the physical, social, and cultural dimensions of their environments across space and over time." Balée (2006, p. 76) has recently defined historical ecology in similar terms.

Rendering such research agendas operational is of course a significant challenge. Recent work in the central Andes addresses precisely these issues (e.g., Contreras 2007; Hayashida 2006; Hesse 2008; Rigsby et al. 2003; Zaro and Umire Álvarez 2005). The long history of research focused on environment and landscape in the central Andes provides a firm grounding, and these recent research programs suggest ways that reciprocal human–environment interactions may be addressed archaeologically. Specifically, they suggest that (1) deliberate anthropogenic landscape modification is more extensive than previously thought and must be recognized and documented using both archaeological and geological techniques, (2) geomorphic dynamism occurs on a temporal scale critical to archaeology, both posing postdepositional problems for archaeologists and suggesting the necessity of identifying environmental challenges faced by pre-Columbian peoples of the central Andes, (3) the relationship between anthropogenic and geomorphic change may often be reciprocal, and (4) anthropogenic landscape change is the material manifestation of diverse imperatives, including both material and ideological motivations.

The relationship of setting-as-landscape to setting-as-environment also is coming into focus in the central Andes. The landscape context of ritual architecture in central Andean societies has often been seen as a significant factor in the location and ritual activities of major prehistoric ceremonial centers (Kolata 1993; Reinhard 1985a). Moreover, as discussed above, major environmental elements such as mountains, rivers, springs, and rocks were invested with ritual significance, acting as ritual architecture in their own right. I have argued elsewhere (Contreras 2007; Rick and Contreras 2006) that central Andean environments not only inspired awe and respect in the form of apotropaic ritual they also, by their very physically apparent power and activity, provided a potential path to naturalized sociopolitical inequality. The possibility of influence or even control over such apparent sources of power—or at least the claim and/or advertisement of such—seems to have been both a potent lure for central Andean peoples generally and a hook that nascent and aspiring elites might exploit (Lumbreras 1993). Conversely, environmental disasters may have constituted potent challenges to prevailing ideology (Bourget 2001; Jennings 2008; Moseley 1990) or produced conditions favorable to new ideologies (Burger 1988, 1993).

Conclusions

If van der Leeuw and Redman's (2002) proposed intellectual sequence is evident in the literature from the central Andes, so too is a changing trajectory of interpretation of indigenous ability to alter the environment (Denevan 1992). The pre-Columbian indigene has gone from passive inhabitant of environments to active shaper of agricultural and ideological landscapes. The central Andes provide a stark and variable environment that is simultaneously a risk-fraught location, an intensified agricultural landscape, and a sacred setting. This combination emphasizes the importance of looking for landscape modification—much evidence of which has emerged only in recent decades—as well as the folly of dismissing environmental influence. Indeed, the two are intimately linked in ways not yet adequately explored.

Environmental variability and/or change (or possibility thereof), the central Andean record demonstrates, can stimulate anthropogenic landscape modification. Conversely, in a linkage certainly demanding more investigation in the central Andes, anthropogenic landscape modification may exacerbate or limit vulnerabilities to environmental shifts in ways that may be intentional or incidental. Investigation of these relationships promises to further archaeology's contribution to the investigation of human sustainability and resilience, highlighting central Andean archaeology's broad relevance to such a field of inquiry.

If archaeology is to successfully address the challenges/questions posed by van der Leeuw and Redman (2002) and Fisher and Feinman (2005), emphasizing its relevance to contemporary studies of sustainability, it must do so by building on detailed and specific studies of local and regional trajectories. Recognition and querying of diverse suites of material evidence and articulation of the subtle interlinkages between human activity and environmental change depend on long-term, detailed histories and fine-grained chronologies. The research summarized here suggests that the central Andes present diverse case studies in the complexity of human–environment interactions; as that complexity becomes better documented, generalizable principles may be distilled out of the ferment.

Explicitly linking sacred landscapes to prehispanic subsistence and risk-management strategies and practices is another important challenge for the archaeology of human–environment interactions. It is clear that in the central Andes all three of these aspects of setting were significant for prehispanic peoples and that the material remains of all three may be preserved and accessible. Investigating the ways in which they are linked promises to shed light on recursive links between humans and their environments as well as underlying worldviews.

Acknowledgments I thank Gary Feinman for encouraging me to write this article, as well as John Rick and David Keefer for guidance in the original research underlying it. Ignacio Cancino provided valuable comments and suggestions on this text, for which I thank him, and six anonymous reviewers provided remarkably thorough and constructive comments. The text also has been greatly improved by Linda Nicholas' careful editing.

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