Chapter 6

Central Andean Environments

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INTRODUCTION

The Andes is a region of great environmental diversity, and the period of human occupation over the last 13,000 or more years has been a time of change in climate and environment. Our understanding of the ancient people of the Andes must be embedded in this physical context. In this chapter, we focus on the Central Andes—or modern day Peru, highland Bolivia, Ecuador, and northern Chile (Figure 6.1). We also recommend Chapter 2 in Moseley (2001) and Chapter 1 in Richardson (1994).

Though lying mostly in the southern tropics, the Central Andes includes high, snow-capped peaks, rich intermontane valleys, well-watered eastern slopes dropping to the Amazon jungle, and arid western slopes descending to a coastal desert broken by irrigable valleys and fronting one of the world's richest fisheries (Figure 6.2). Within this general setting lie a multitude of microenvironments, the location, size, and productivity of which have varied as climate changed and natural and cultural forces altered the landscape and necessarily affected human-environment interactions. As one outcome of this diversity, ancient Andean people found and domesticated a wide variety of plants adapted to the range of available habitats (see National Research Council 1989; see Chapter 7 in this volume). The number of domesticated animals, however, was not correspondingly large, consisting of guinea pigs, several birds, llama, and alpaca; the dog came into the region early but already domesticated.

Technology, history, cultural practices, religion, perception, and individual and group idiosyncrasies can all affect the way a society and its members dynamically interact with their environment and respond to environmental and climatic change (Sandweiss et al. 2001). Nevertheless, people must make a living from the natural world around them, and when that world changes, they must respond in some way. How humans took advantage of, altered, or succumbed to the physical conditions imposed by the Andean region through time is an important part of regional prehistory. Indeed, the special characteristics

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Figure 6.1. Map of the Central Andes, with sites and places mentioned in the text. (Daniel Sandweiss).

of the Central Andean environment play major roles in many influential if controversial ideas about the Andean past (e.g., rich ocean: maritime foundations of Andean civilization, Moseley 1975 but cf. e.g., Raymond 1981; highland microenvironments: ecological complementarity/"verticality," Murra 1972 but cf. e.g., van Buren 1996).

THE EIGHT NATURAL REGIONS

Peruvian geographer Javier Pulgar Vidal (1987) divides Peru into eight "natural regions" based on climate, altitude, and indigenous land use (Figure 6.2). With some alterations, these zones apply to the rest of the Central Andes. After reviewing this modern classification, we will note some of the natural and cultural factors that have caused change in the

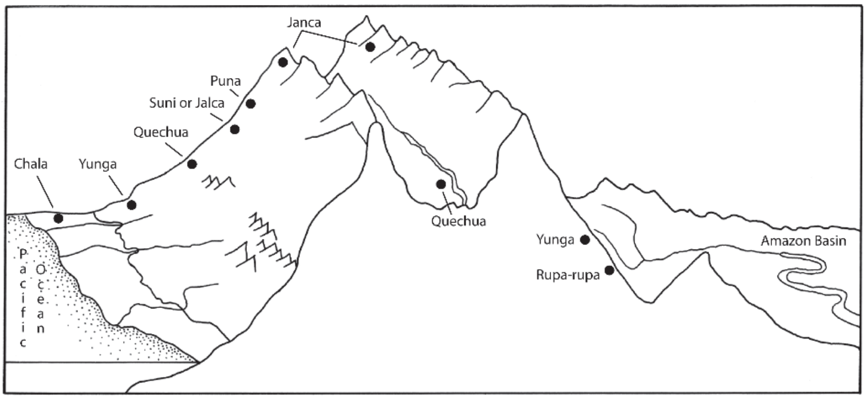

Figure 6.2. Cross-section of the Central Andes showing the major environmental zones according to Pulgar Vidal (1987). (Adapted from Richardson 1994).

Andean environment over the span of human occupation and briefly sample some of the major issues in the study of prehistoric human-environment interaction in this region.

Pulgar Vidal (1987) uses Quechua folk terminology to label his "natural regions." Though these regions are organized from west to east and largely along the altitudinal gradient that so strongly affects local climate and environment in this tropical region, there are important latitudinal (north-south) gradients as well. For instance, coastal aridity increases to the south from the Ecuadorian-Peruvian border to the Atacama Desert of northern Chile, while the average impact of El Niño events decreases along the same trend. The high elevation puna zone (see below) of central and southern Peru grades north into the moister paramo of Ecuador and south into the more arid Salt Puna and Dry Puna of northern Chile and adjacent regions.

Pulgar Vidal's (1987) first zone, *chala*, runs from the Pacific shore up the western slopes to about 500 masl. Though a desert in Peru and Chile, this coastal zone is covered with dense fog or garúa in the austral winter. The presence of a desert on a tropical coast results from two factors: the rain shadow of the high Andes and the cold Humboldt or Peru Current that flows from Antarctica north as far as the Illescas Peninsula in northern Peru. Above 200 masl and up to 1,000 masl in places, the garúa permits a xerophytic plant community known as lomas that provided some plant foods, fuel, and faunal resources for early inhabitants of the western slopes. The desert becomes more extreme as one moves south, while to the north (into Ecuador) the coastal zone receives more precipitation but garúa does not form. The chala is broken by river valleys that run perpendicular to the coastline; some have year-round flow while others are ephemeral. From the earliest occupation, the valleys have provided people with water and plant and animal resources. Irrigation and, with it, intensive farming of the fertile valley floors began at least 4,400 years ago in some coastal valleys and probably as early as 6,100 years ago in quebradas of the western slopes (Burger 1992; Dillehay et al. 2005; Grieder et al. 1988; Quilter et al. 1991; Shady Solis et al. 2001). Finally, thanks largely to nutrient upwelling in the Humboldt Current, the Pacific Ocean off Peru and Chile constitutes one of the world's richest fisheries. Even the first inhabitants of the region made extensive use of marine resources as much as 13,000 years ago (Sandweiss et al. 1998, 1999; see also Chapter 10), and fishing has remained important through the present.

The next zone is the *yunga*, present on the western slopes overlooking the Pacific Ocean from 500 up to 2,300 masl, and on the eastern slopes overlooking the Amazon basin from 2,300 down to 1,000 masl (Pulgar Vidal 1987). Cut by deeply incised river valleys and dry quebradas, the western or maritime yunga consists of parched hillsides and mountain slopes where only lomas plants grow (at the lower elevations) during the winter. Under normal circumstances, agriculture is possible only in the valleys. The eastern or fluvial yunga consists of forested slopes, deep valleys, and lateral quebradas. This zone receives more regular and abundant precipitation than the maritime yunga and offers forest products as well as potential for agriculture. Most indigenous Andean crops grow in irrigated regions of both the chala and the yunga zones.

Moving up, the *quechua* zone lies between 2,300 and 3,500 masl and includes some of the most productive land in the Central Andes. Here the terrain rises in smooth steps above rich valleys. Rainfall is seasonal and both rain fed and irrigation agriculture is possible. In later prehistory, terracing became an important means of increasing the amount of arable land in the quechua zone and above. The quechua zone is the upper limit of maize cultivation, and many other Andean crops grow well here. Average annual temperature ranges between 11° and 16° C, with maximum temperatures as high as 29° C and minimums as low as −4° C. Though there are some seasonal differences, diurnal variation is much more striking and significant, as geographer Carl Troll (1958) pointed out half a century ago. In the higher reaches of the quechua zone, warm days can alternate with nights below freezing. Here, and in higher elevation zones, Andean people have long taken advantage of this cycle to make freeze-dried potatoes known as chuño and dried camelid (llama, alpaca, and relatives) meat called charqui (jerky in American supermarkets and convenience stores). These are storable staples with a long shelf life.

It is in the quechua zone (Pulgar Vidal 1987) that one reaches an important potential barrier for human habitation: the effects of decreasing oxygen saturation with altitude. Looking at biological studies of the effects of altitude on human health and reproduction, both Richardson (1992) and Aldenderfer (1998) have suggested that the initial colonization of the Andes above about 2,850 masl may have required a multi-generational period of gradual adaptation to altitude.

Pulgar Vidal (1987) defines the region from 3,500 to 4,000 masl on both the eastern and western sides of the Central Andes as *suni* or *jalca*. This is a steeper terrain than the quechua zone, with high relief and narrow, rocky quebradas. Only limited areas are suitable for agriculture. The climate is cool, with average annual temperatures between 7° and 10° C and a maximum-minimum range of 20° to −16° C. Many high altitude Andean crops grow here, including the chenopods quinua and cañihua, the lupin tarhui, the fava bean or haba, and tubers such as oca and olluco.

The highest permanently habitable zone is the *puna*, from 4,000 to 4,800 masl (Pulgar Vidal 1987). This is a relatively low relief, high altitude grassland that appears as north-south strips including the altiplano of southern Peru and Bolivia around Lake Titicaca. The puna is a cold region, with average annual temperature between 0° and 7° C. Like the quechua and suni zones, however, there is strong diurnal variation, and days can be quite warm. The potato (*Solanum tuberosum*) is the most important of the few indigenous domesticates that grow in the puna zone. Other important crops in the puna zone include cañihua (*Chenopodium pallidicaule*), which grows to 4,400 masl, and quinoa (*Chenopodium quinoa*), which grows in the puna zone in Ecuador but only to about 4,000 masl in Peru, Bolivia, and northern Chile (National Research Council 1989). However, this region is the home of the Andean camelids, the wild guanaco (*Lama guanicoe*) and vicuña (*Lama* *vicugna*) and the domestic llama (*Lama glama*) and alpaca (*Lama pacos*). These animals were an important source of meat and wool for Andean peoples, and domesticated llamas also served as beasts of burden (though with a very limited maximum load, about 25 kg or one sack of potatoes).

The *janca* zone runs from 4,800 masl to the top of the Andean peaks (Pulgar Vidal 1987). Though visited by prehistoric people (e.g., Reinhard 2005), the low temperatures and lack of oxygen make this a poor place for habitation. Still, the glaciers and snowcapped peaks of the janca are the origin of the rivers that water the Central Andes.

On the eastern slopes of the Central Andes, below the yunga lies the *rupa-rupa* or high jungle zone from 400 to 1,000 masl (Pulgar Vidal 1987; it is called ceja de selva or eyebrow of the jungle in Peruvian Spanish). This is a warm, humid, well-vegetated region of broken terrain cut by valleys and quebradas. Average annual temperature ranges from 22° to 25° C and it never freezes. Both farming and herding can be practiced here.

The final zone is the Amazonian jungle or *omagua*. This hot, wet environment has many peculiarities of importance for understanding human adaptations, but it lies outside the scope of this chapter (see Chapter 12 in this volume).

CLIMATE AND ENVIRONMENT

In the Andes, climate affects the position and size of glaciers; the location, frequency, seasonality, and quantity of precipitation; sea level; the position of the snow line and of vegetation belts; the frequency and intensity of El Niño/Southern Oscillation (ENSO) events; and plant and animal distributions. Furthermore, the Andes are located on a subducting plate margin (the oceanic Nazca Plate is sliding under the continental South American Plate), so the region is subject to frequent seismic activity and volcanism. Earthquakes, volcanic eruptions, and the tsunamis sometimes associated with seismic activity not only have a devastating impact on the people, but on the towns, cities, and economic infrastructure such as irrigation works (de Silva and Francis 1991; Giesecke and Silgado 1981; Oliver-Smith 1986). However, because of the unusual shallow-angle subduction under northern and central Peru, active volcanism does not occur here as it does in Ecuador and in southern Peru, Bolivia, northern Chile, and Argentina (Barazangi and Isacks 1976). Consequently, this sector of the Central Andes lacks catastrophic volcanic eruptions and obsidian (a volcanic glass highly prized as a lithic raw material). However in southern Peru there have been major volcanic eruptions, such as that of Huaynaputina in AD 1600, which blanketed the region with ash (de Silva and Zielinski 1998).

Paleoclimatic paleoenvironmental studies in the Central Andes are ongoing, with new discoveries yearly. Here, we summarize the major sources of information on past conditions and changes; later, we will point to some important instances of climatic or environmental alterations that correlate with cultural change. To keep up with the cutting edge, readers are encouraged to follow the contents of journals such as *Science*, *Nature*, *Geology*, *Quaternary Research*, *Quaternary International*, *Quaternary Science Reviews*, *Palaeogeography*, *Palaeoclimatology*, *Palaeoecology*, and *Geoarchaeology* in addition to the standard archaeological literature.

The high Andes offer a multitude of paleoclimatic archives. These include ice cores from ice caps and glaciers (sometimes with annual resolution) (e.g., Thompson et al. 1985, 1995, 1998), glacial deposits (e.g., Rodbell and Seltzer 2000), wetland and lake cores (e.g., Abbott et al. 1997), salar (salt flat) cores (Geyh et al. 1999), packrat middens

(Betancourt et al. 2000), archaeological sites (e.g., Aldenderfer 1998), and others. In contrast to the highlands, the extreme aridity and cool oceanic waters along the Central Andean coast mean that this region lacks pollen catchments and corals, two important sources of paleoclimatic data in other coastal regions. Glaciers never extended to the tropical Andean coast. Cores from the ocean floor have critical hiatuses through the middle of the Holocene and/or their recent segments have not been published in detail. Consequently, archaeological sites and their contents play an important role in reconstructing coastal climate over the 13,000 years of human presence (Sandweiss 2003).

Every paleoclimatic archive requires interpretation; many are not directly suited to the scale or locale of archaeological sites (Dincauze 2000), and extending inferences beyond the immediate region of the record requires recognizing teleconnections (long-distance climatic interactions) and positing that the same teleconnections operated at the time of interest. Paleoclimate modeling is another approach to reconstructing past environments and climates in the Andes. However, thus far few models operate at the human scale that would be of most use to archaeologists, and there is little agreement among different models at any spatial scale.

Humans had arrived in the Andes by about 13,000 years ago, at the end of the Pleistocene epoch as the last ice age was drawing to a close (Dillehay 2000; Lavallée 2000). Through most of the world, this was a period of radical and often abrupt climatic change (Taylor et al. 1997, inter alia). Nor was the succeeding Holocene epoch (the last 11,400 years) the time of stability once envisaged (e.g., Stager and Mayewski 1997; see articles in *Palaeogeography*, *Palaeoclimatology*, *Palaeoecology* vol. 194[1–3], 2003, for recent, regional Andean data). Though swings were less radical than in the Pleistocene, Holocene climatic variability occurred during a time of increasing human population size and density, increasing sedentism, and developing dependence on agropastoral subsistence systems—in other words, a time of ever greater vulnerability to change.

From the end of the Pleistocene Epoch to the present, global climate has cycled through many phases and events with local, Andean expressions, at millennial, centennial, decadal, and interannual time scales. The earliest well-dated archaeological sites in the Central Andes date to the Younger Dryas, a 1,600-year cold reversal in much of the world, the last gasp of the waning ice age from 13,000–11,400 cal yr BP. In much of the world, the mid-Holocene (9000–3000 cal yr BP) was a time of greater than present warmth; in the Atacama Desert of northern Chile and parts of southern Peru, this appears to have a period of great aridity and low human populations labeled by Núñez as the "archaeological silence" (Grosjean et al. 1997; Sandweiss et al. 1998; however, as usual there is controversy, see for example Betancourt et al. 2000; Grosjean et al. 2001). At the same time, the first part of this period (9000–5800 cal yr BP) saw mildly increased precipitation on the north coast of Peru. The second part of the mid-Holocene (5800–3000 cal yr BP) witnessed the rise of monument building, fishing, irrigation farming, complex societies on the central and north coasts of Peru and in the adjacent highlands in a climatic context of coastal desiccation and increased interannual variability. To the south, these developments tended to lag, appearing as much as a millennium later, toward the close of the dry period (Sandweiss 2003; Calgero Santoro, personal communication)

In the Central Andes as elsewhere, people have played major roles in changing their environment, not always for the better (Dincauze 2000; Redman 1999). Humans are active geomorphic agents (Denevan 1992; Erickson 1992; Hooke 2000) as well as frequent meddlers with the biota (Gade 1999; Johannessen and Hastorf 1990). As in much of the world, the adoption of agriculture had the most visible impact in the Andes, both by generating new species and by changing the landscape and available habitats (Denevan 2001; Zaro and Umire 2005). In quebradas of the western slopes, small-scale irrigation began by 6100 cal yr BP and led to "artificially created wet agroecosystems" (Dillehay et al. 2005). On the desert coast, the advent of irrigation systems (beginning perhaps as early as 4400 cal yr BP) expanded the vegetated portion of valleys from narrow gallery forests to the entire floodplain and even in places onto the desert margin. Much later, during the Middle Horizon, terracing began to transform the high Andes by radically increasing the amount of flat surface available for planting (Moseley 2001: 232–233), while the construction of raised fields in the Lake Titicaca region during the first millennium AD (1950–950 cal yr BP) vastly enhanced the agricultural potential of that harsh region (e.g., Erickson 1988, 1992). One study has found that Andean terraces were particularly effective in preserving soil quality even after centuries of agricultural use (Sandor and Eash 1991, 1995). In the Llanos de Mojos of Bolivia raised fields were also constructed over a vast area (Denevan 1966; Erickson 1995; Walker 2004). In addition to farming, other deliberate or inadvertent human actions altered environments and the resources that they offered to people, and even deliberate actions often had unintended consequences (Redman 1999).

CLIMATIC AND ENVIRONMENTAL CHANGE AND RESOURCE KNOWLEDGE IN ANDEAN PREHISTORY: A SAMPLER

In this section, we briefly review several case studies of human-environment interaction in the Central Andes. This includes not only human adaptations to constantly changing environments and distributions of plant and animal resources, but also the knowledge of geological resources for the production of artifacts such as stone tools. Figure 6.1 shows the location of sites and places mentioned in this section.

Climatic Control on Obsidian Availability

Among the many spatially discrete resources that the Andes offer, obsidian is one of particular utility both for the ancient people and for archaeologists. Each source of obsidian has a unique chemical signature, so obsidian in archaeological sites can be traced back to its origin. Over the past twenty-five years, Richard Burger and his colleagues have identified the major types of Andean obsidian and located most of the sources (see Burger et al. 2000 for a review and demonstration of the anthropological utility of obsidian sourcing). Obsidian debitage from the Terminal Pleistocene component at Quebrada Jaguay is among the earliest samples studied, and all of the fragments came from the Alca source, some 165 km distant from this coastal fishing site at elevations of 2,800 to 3,800 masl and higher (Jennings and Glascock 2002; Sandweiss et al. 1998). Only 20 km further away along a better-watered route, the 4,900 masl Chivay obsidian source was extensively used later in prehistory, though no Chivay material was present at Quebrada Jaguay. Did this difference represent early territoriality or inaccessibility of the Chivay source? Preliminary fieldwork and dating of glacial features by glacial geologist Harold Borns (personal communication) and Daniel Sandweiss support the latter and suggest that a Younger Dryas age (ca.13,000–11,400 cal yr BP) glacial readvance as low as 4,650 masl would have covered the Chivay source during the Terminal Pleistocene occupation at Quebrada Jaguay.

Sea Level, Site Preservation, and Early Maritime Adaptations

Despite C. Barrington Brown's (1926) early report of preceramic sites in far northern Peru, it was the work of Junius Bird (et al. 1985) at Huaca Prieta, northern Peru, in the late 1940s that put the Central Andean coastal preceramic on the map. Subsequent research on this epoch focused on the central Peruvian coast, and in the 1960s Edward Lanning (e.g., 1967) devised an influential cultural sequence for the coastal preceramic based on his work at Ancón-Chillón near Lima. Lanning did not find any significant use of marine resources until around 5800 cal yr BP, with his Encanto phase. At the same time, James B. Richardson III was beginning research on the preceramic of far northern Peru, where he found marine mollusks in Amotape phase campsites dating as early as 12,800 cal yr BP. Adding these data to other whispers of pre-5800 maritime adaptations, Richardson (1981) sought and found an explanation for the spatial distribution of such evidence: early fishing seemed to occur only where the continental shelf was narrow. As he pointed out, these are the sectors of ancient shorelines that suffered the least horizontal displacement as sea level rose with deglaciation from 21,000–5800 cal yr BP. Places like Ancón-Chillón have a relatively wide shelf, so the shoreline moved fairly quickly until sea level stabilization, drowning any early maritime sites that might have existed there. Confirmation of Richardson's hypothesis of sea level rise and settlement loss came in the 1990s, with the discovery and excavation of very early maritime sites such as Quebrada Jaguay (~13,000–8250 cal yr BP), and Quebrada Tacahuay (Keefer et al. 1998; Sandweiss et al. 1998; see Sandweiss, in this volume).

El Niño Frequency Change and Correlated Cultural Change

Another line of environmental archaeological research initiated by Richardson (1973) in far northern Peru is the recognition of changing ocean currents in the Mid-Holocene from the contents of archaeological middens. Over the next thirty years, Richardson and his colleagues pursued this issue, eventually using archaeological mollusk and fish remains to determine likely variations in the frequency of El Niño (ENSO): a period of few or no ENSO events and warmer than present coastal waters in northern Peru from ~9000–5800 cal yr BP; a period of strong but infrequent ENSO events and cool waters along all of Peru from ~5800–3000 cal yr BP; and conditions within the modern range since the latter date (Sandweiss et al. 2001). Though these conclusions have been debated, they are now well substantiated by multiple paleoclimatic records throughout the Pacific basin (see summary in Sandweiss 2003). The climatic transition at 5800 cal yr BP correlates with the onset of monumental construction on the Peruvian coast, while the transition at 3000 cal yr BP correlates with the abandonment (at the end of the Initial Period) of the last temples in this tradition after almost 3,000 years of development. Carefully nuanced further research is needed to see if there are any causal or explanatory links in these correlations.

Vulnerability of Agricultural Systems

Agrarian collapse is another research area that highlights human-environment interaction. Plant cultivation began on the coast of Ecuador, over 11,000 years ago (Piperno and Pearsall 1998; Piperno and Stothert 2003) and irrigation systems were in place on the western (Pacific) slopes of northern Peru by about 6000 cal yr BP (Dillehay et al. 2005). In the highlands, the earliest evidence of agriculture dates to the end of the Late Preceramic Period around 4000–3700 cal yr BP in Cotahuasi (Perry et al. 2006), while small-scale irrigation of the interandean valleys in Cajamarca began in the late Initial Period between ca. 3000 and 2500 cal yr BP (Burger 1992: 111). Large-scale terracing and, in the Lake Titicaca region, raised fields were first constructed in the second half of the first millennium AD (ca. 1450–950 cal yr BP). None of these systems was stable in the long term, and some suffered spectacular, precolumbian collapses. The causes for agrarian collapse have been hotly debated, with suggestions for individual cases ranging from tectonic movement to engineering incompetence to climatic change. Space does not permit detailed discussion of case studies, but following are brief references to major examples. In the Moche area of northern coastal Peru, field systems built from the end of the Early Intermediate Period (ca. 200 BC-AD 600 or 2150–1350 cal yr BP) through the early Late Intermediate Period had contracted significantly before the end of the Late Intermediate Period (ca. AD 1100–1440 or 850–510 cal yr BP). Moseley (1983 inter alia) posits tectonically driven landscape alteration as the primary cause of field abandonment, while others suggest human factors (e.g., Pozorski and Pozorski 1982). In far southern Peru, just north of Ilo, Clement and Moseley (1991) document the contraction of a small-scale, spring-fed coastal irrigation system also apparently as the result of tectonic activity during the second millennium AD. In the same area, but slightly further inland, Moseley and colleagues found evidence not only for agrarian collapse but also for radical social reorganization at about AD 1350 (ca. 600 cal yr BP). In the Ilo river valley, a large-magnitude flood associated with El Niño destroyed field systems, the main canal, and most dwellings on the valley slopes and bottoms; along with agrarian contraction and demographic collapse, the local, Chiribaya culture shows significant change in cultural patterns following this event (Reycraft 2000; Satterlee et al. 2001). In the altiplano around Lake Titicaca, during the first millennium AD, raised field agriculture vastly increased the agrarian productivity of this inhospitable, high-altitude environment (e.g., Erickson 1988). Early in the second millennium AD, however, raised field technology was abandoned and not rediscovered until late in the twentieth century. Kolata and his colleagues (e.g., Binford et al. 1997) have argued that the proximate cause of agrarian collapse in this region was climatic change evident in a variety of paleoclimatic archives. Erickson (1999) has questioned their interpretation and the use of what he characterizes as "neo-environmental determinism" in causal explanations of prehistoric Andean culture change.

CONCLUSION

The correlation of the changing paleo-environment with cultural change in the Central Andes is still in its "infancy," but the last thirty years of research have demonstrated that understanding climatic change and natural disasters is critical to reconstructing cultural trajectories in the Andes. From this brief sampler, it is evident that human-environment interaction remains an important if hotly debated issue in the understanding of ancient Andean peoples. Given the physical and climatic nature of the region over the last 13,000 years, that is hardly surprising.

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