

Early Settlement in the High Andes

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Summary

The Andean highlands of western South America spans 7,000 km from the equator to Patagonia and reaches altitudes of 7,000 m. Extreme cold, hypoxia, and low bioproductivity impose a distinct set of challenges to human survival and reproduction. This adaptive setting has inspired considerable archaeological and genetic research, which seeks to define the timing and nature of the adaptive process. Current evidence establishes that Paleoindian populations with fluted-point projectile technology first entered the highlands around 12.8 cal. ka. Paleoindian use of the highlands over the subsequent one thousand years appears to have been ephemeral. During the Early Archaic period (11.7–9.0 cal. ka), a culturally and genetically distinct population appears to have replaced the Paleoindian population in the highlands where they eventually established year-round settlement systems. Early Archaic cultural adaptations included large-mammal hunting, tuber foraging, animal-hide technology, logistical mobility, and egalitarian social structure. Potential genetic adaptations include selection for respiratory and cardiovascular strength and enhanced starch digestion capacity. Human adaptation to the Andean highlands thus appears to have been a multifaceted process that transpired over some four thousand years. Although current evidence favors a model of gradual adaptation, a more rapid adaptive process cannot yet be excluded. Paleoindian sites remain woefully sparse, which may indicate limited use or a sampling problem. And although recent genetic and isotopic analyses have been incisive, they are restricted to few samples from relatively late contexts. Continued investigations at the intersection of traditional archaeological methods and new biomolecular methods are likely to resolve outstanding questions soon and create opportunities to explore more-nuanced questions about the peopling of the high Andes.

Keywords: Andes Mountains, Paleoindian period, early Archaic period, genetics, high altitude, foragers, hunter-gatherers

Subjects: Archaeology

Introduction

Few terrestrial landscapes challenge biological survival to the extent of high-elevation landscapes. Organisms inhabiting elevations above 2,500 m (8,000 ft) contend not only with cold temperatures and limited biological resources but also with low oxygen and high solar radiation, all of which challenge survival and reproduction (Beall 2014; Moore, Charles, and Julian 2011; Moran 2008; Witt and Huerta-Sánchez 2019). It is ostensibly for these reasons that the world's highest plateaus were among the final frontiers of human expansion (Aldenderfer 2006a). The South American Andes are one of just two places in the world—the other being the Tibetan Plateau—where hospitable lowland environments would have been relatively inaccessible from interior highland regions. Nonetheless, early human populations ultimately solved those survival

and reproductive challenges in the high Andes, establishing permanent highland populations and paving the way for agropastoral economies and eventual state formation (Janusek 2004; Stanish 2003).

This remarkable feat of human adaptability has driven considerable archaeological research. The review presented here summarizes the current state of knowledge for the peopling of the high Andes. Specifically, the review examines when humans first entered the Andean highlands, when they first established year-round settlement systems in the highlands, and the behavioral and genetic adaptations that facilitated the peopling process. Before we examine these questions, a brief summary of high Andean ecology presents the adaptive context.

Ecology of the High Andes, 15–9 cal. ka

The Andes Mountains are a north–south trending mountain chain spanning over 7,000 km from Venezuela to southern Chile and extending from sea level to 7 km in altitude at Aconcagua, Argentina (figure 1). *Andean highlands* refers to regions above 2.5 km in altitude, an area that covers approximately 1.1 million km² (Danielson and Gesch 2011). Above this altitude, lowland organisms commonly experience acute mountain sickness, which includes headaches, dizziness, and reduced work capacity (Beall 2014). More extreme but rare effects include pulmonary and cerebral edema—the buildup of fluid in the lungs and brain, respectively, which can lead to death.

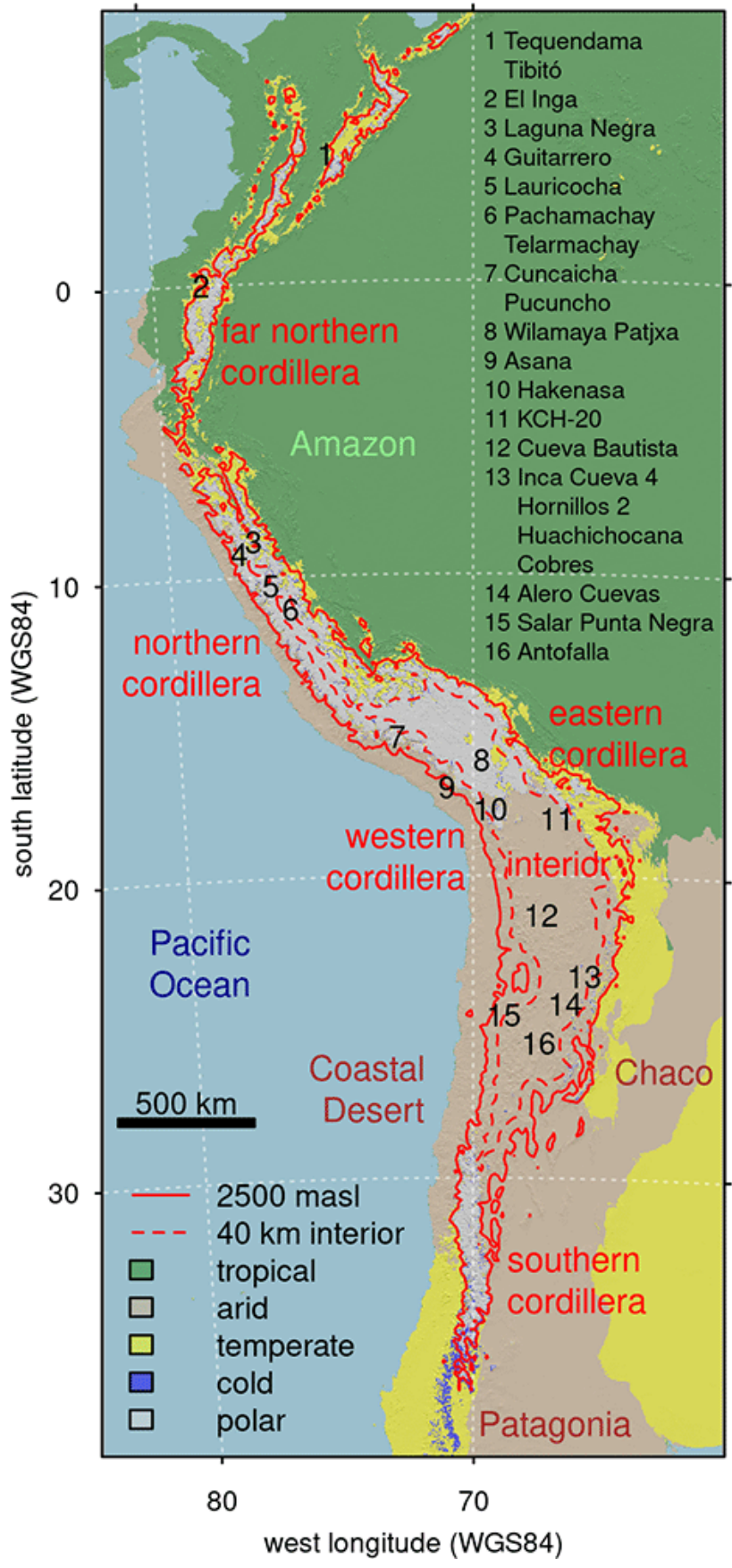


Figure 1. The Andean highlands of western South America and sites discussed in text. The highlands are regions above 2500 m above sea level, defined here using Global Multi-resolution Terrain Elevation Data (Danielson and Gesch 2011). Climatic conditions are polar and arid according to Köppen-Geiger climatic classification (Beck et al. 2018). Sites include Paleoindian (13–11 cal. ka) and Early Archaic (11–9 cal. ka) period sites.

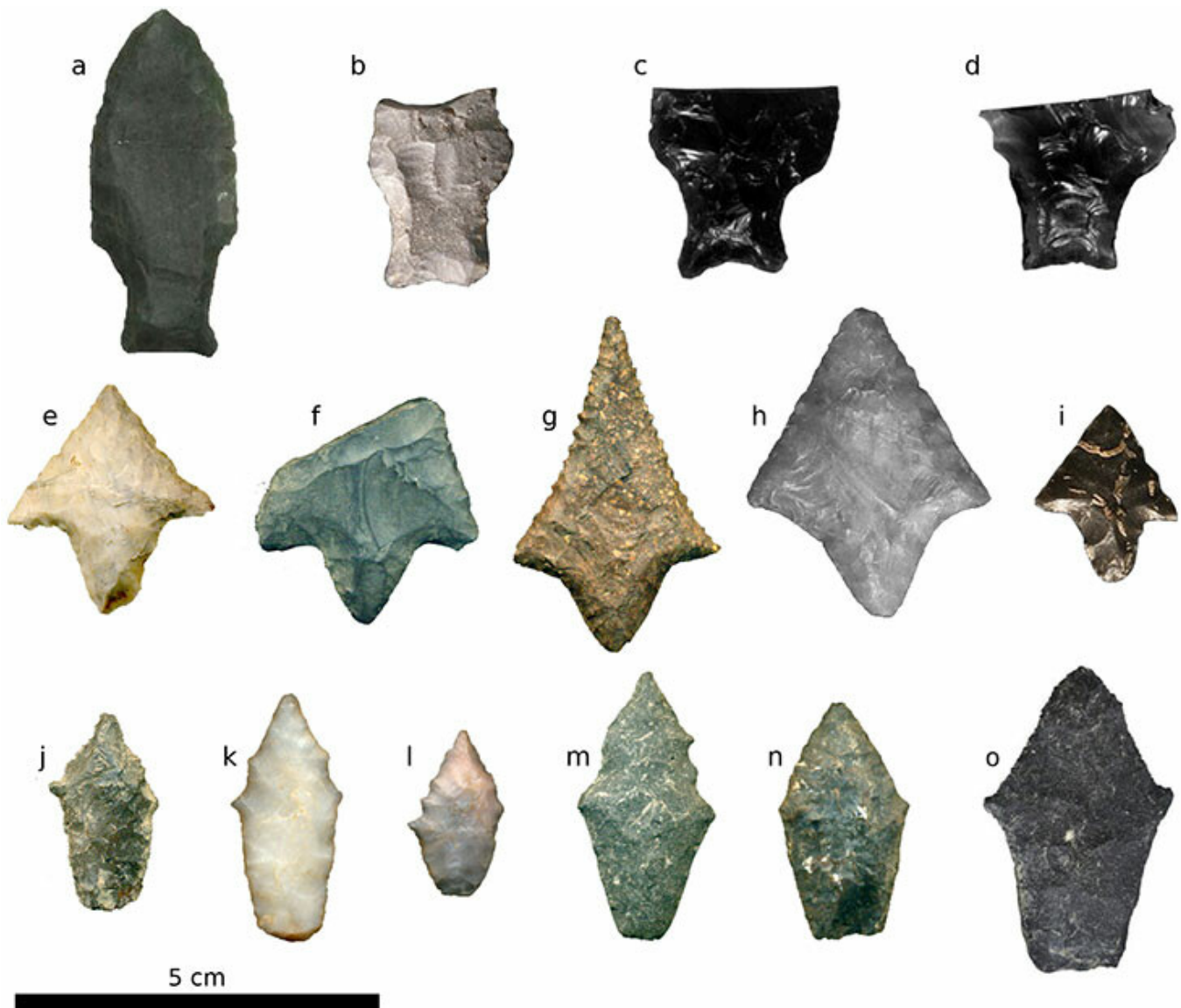


Figure 2. Paleoindian (a–d) and Early Archaic (e–n) projectile points of the High Andes. (a–d) fishtail points from (a) the eastern cordillera (Patané Aráoz and Nami 2014), (b) the western cordillera (Rademaker et al. 2014), and (c and d) the northern cordillera (Nami 2014). (e–h) Contracting broad-stem points from the (e–g) interior [points collected by Klink (2005) and Aldenderfer (Craig 2011)] and (h and i) western cordillera (Rademaker et al. 2014; Sandweiss and Rademaker 2011). (j–o) Eared points from the (j–n) northern interior [points collected by Klink (2005), Aldenderfer (Craig 2011), and Haas et al. (2015)] and (o) central interior (Capriles et al. 2018).

Not only are the Andean highlands starved of oxygen, it is also an extremely cold environment. The Köppen–Geiger climatic classification scheme, which is based on seasonal air temperatures and precipitation values, identifies the northern high Andes as polar tundra and the southern high Andes as arid, cold desert (Beck et al. 2018). Temperature and precipitation are seasonal; annual highs occur in January (warm and wet season), and lows occur in July (cold and dry season). Southern latitudes experience greater seasonal variation in temperatures and less overall precipitation than northern latitudes. Consider, for example, contemporary weather station data from the central Andean city of Juliaca, Peru (15.5°S latitude, 3,800 masl) and south Andean city of San Antonio de los Cobres, Argentina (24.2°S latitude, 3,800 masl). Average daily high temperatures in July (austral winter) range from 16°C in Juliaca to 5°C in San Antonio de los Cobres, and daily lows range from -5°C to -10°C, respectively. Thus, diurnal temperatures can vary considerably in July, and average temperature swings range from 15°C to 20°C. Average daily high temperatures in January (austral summer) are around 16°C in both locations. Average January precipitation ranges from 75 mm in Juliaca to 140 mm in San Antonio de los Cobres. Both regions experience a virtual absence of precipitation in the austral winter.

A regional ecosystem known as the *puna* characterizes much of the high Andean environments. The *puna* is broadly divided into the wet *puna* to the north and dry *puna* to the south. Grasses and shrubs comprise the major flora, and because of the altitude, there are few trees. Although much of the Andes Mountains is rugged, an expansive high-plain region known as the *Altiplano* lies at the heart, centered on Lake Titicaca—a large freshwater lake spanning more than 8,000 km². A large portion of the southern high Andes intersects the Atacama Desert—the world’s driest nonpolar desert. Economically important animal species in the high Andes include the vicuña (*Vicugna vicugna*), guanaco (*Lama guanicoe*), taruca (*Hippocamelus antisensis*), lesser rhea (*Rhea pennata*), montane cuy (*Cavia tschudii*), and carache (*Orestias* sp.).

Late Pleistocene ecological conditions in the high Andes were different from contemporary ecological conditions. The Antarctic Cold Reversal (14.6–12.9 cal. ka) and Younger Dryas (12.9–11.7 cal. ka) periods of the Terminal Pleistocene were colder and wetter than current conditions (Palacios et al. 2020). Antarctic Cold Reversal temperatures were about 3°C cooler than in the 21st century, and annual precipitation levels were about 10 percent higher (Palacios et al. 2020; Thompson et al. 2003). A number of extinct megafauna taxa—including gracile llama (*Lama gracilis*), ground sloth (*Catonyx* sp., *Diabolotherium nordenskioldi*, and *Megatherium* sp.), horse (*Hippidion* sp. and *Equus neogeous*), macrauchenia (*Macroauchenia patachonica*), and gomphothere (*Cuvieronius hyodon*; Capriles and Albarracin–Jordan 2013; Correal Urrego 1990; Villavicencio and Werdelin 2018)—were present in the high Andes until at least 12.8 cal. ka. Modern high Andean climatic conditions were largely in place by the Early Holocene epoch (11.7–9 cal. ka). The Younger Dryas was a transitional period of warming and glacial retreat except on the Altiplano, where glacial advance continued because of locally elevated precipitation levels (Palacios et al. 2020).

Human Arrival in the High Andes, 12.8 cal. ka

More than a century of archaeological investigation in the high Andes and surrounding regions allows us to identify a strong signal of human arrival. Genetic evidence indicates that North and South American populations split between 15.8 and 14.2 cal. ka (Lindo et al. 2018) and that the peopling of the Andes region began sometime between 12.9 and 11.7 cal. ka (Harris et al. 2018). The timing of the earliest well-documented projectile point forms in South America is generally consistent with these DNA-based estimates. Fishtail projectile points (figure 2a–d) date to 13.3–11.3 cal. ka, and Paiján points date to 12.8–9.6 cal. ka (Maggard 2015). The sum of genetic and archaeological evidence suggests that human populations first arrived in the greater Andean region around 13 cal. ka, which constrains entry into the highlands to that time or later.

Reviews of early archaeological sites in the highlands suggest entry between 12.7 and 11.3 cal. ka (Núñez, Grosjean, and Cartajena 2001; Rademaker et al. 2014; de Souza et al. 2021; Yacobaccio 2017). A composite dataset of 1,683 cultural radiocarbon dates from the Bolivian Altiplano and interior Atacama regions reveals the first clear cultural signal after approximately 12.8 cal. ka, indicating use of the highlands by that time (Gayo, Latorre, and Santoro 2015). Collectively, these meta-analyses converge to suggest that initial entry into the highlands was around 12.8 cal. ka.

The presence of fishtail fluted projectile points in the highlands is broadly consistent with that estimate. Fishtail fluted points have been securely identified in various parts of the highlands, including at the sites of El Inga in the far northern cordillera of Ecuador (Bell 1960; Mayer-Oakes 1986), Laguna Negra in the northern cordillera of Peru (León Canales et al. 2004), Salar Punta Negra in the western cordillera of Chile (Grosjean, Núñez, and Cartajena 2005), and the Pucuncho site in the western cordillera of Peru (Rademaker et al. 2014). Two ^{14}C dates on wood charcoal from a buried stratum containing fishtail points at El Inga fall in the range of 12.6 to 12.1 cal. ka (Nami and Stanford 2016). In northwestern Argentina, a loosely provenienced fishtail point—the Cobres artifact—has been reported (Patané Aráoz and Nami 2014), and a potential fishtail point has been noted near Antofalla but remains unconfirmed (Grosjean, Núñez, and Cartajena 2005). The widespread but rare occurrence of fishtail points in the high Andes offers a definitive signal of an early but faint human presence that aligns with the radiocarbon record. Notably, Early Paiján points, which date to 12.8–11.2 cal. ka on the north Pacific coast (Maggard 2015), are not currently reported in the highlands, suggesting that cultural population had not penetrated the highlands during the Late Pleistocene.

Current evidence is thus relatively clear in identifying Paleoindian populations as the first to enter the high Andes, beginning around 12.8 cal. ka. This population was a subset of the broader fluted-point cultural phenomenon that spanned the Americas, potentially a subset that hailed from southeastern North America (Nami 2020). Although projectile point fluting offers the technofunctional benefits of shock absorption (Thomas et al. 2017), it is a culturally unique technology that has never been observed elsewhere in the world or at other times. Fluted points in the Andean highlands thus signal the arrival of that cultural population.

DNA reveals that the inferred cultural expansion may have corresponded to a genetic one. Cluster analysis of whole-genome sequences from individuals at the Andean highland sites of Lauricocha (8.6–3.6 cal. ka) and Cuncaicha Rockshelter (9.0–8.4 cal. ka) show broad genetic affinity with other Native American groups and Beringian populations (Fehren-Schmitz et al. 2015; Posth et al. 2018). Similarly, a whole-genome analysis of an individual from the Andean highland site of Soro Mik'aya Patjxa (6.8 cal. ka) reveals a genetic component found in Siberian populations and other early North American individuals, including USR1, Anzick-1, Saqqaq, and Kennewick (Lindo et al. 2018). Although Late Pleistocene human DNA from the highlands is lacking, the sum of the material and genetic evidence suggests that Paleoindian populations first entered the highlands around 12.8 cal. ka.

Paleoindian Adaptation, 12.8–11.7 cal. ka

Despite a clear signal of Paleoindian presence in the highlands, Paleoindian sites remain extremely rare, constraining our understanding of adaptive strategies. Nonetheless, this faint signal is instructive in its own right. The paucity of sites contrasts with other parts of South America where such sites are more common (Prates and Perez 2021) and persists despite dozens of systematic investigations documenting hundreds of early sites and thousands of projectile points in the highlands (Aldenderfer 1998; Bandy 2006; Bauer 2007; Capriles et al. 2018; Cipolla 2005; Grosjean, Núñez, and Cartajena 2005; Haas et al. 2015; Klink 2005; MacNeish et al. 1983a; Núñez 1980, 1981; Núñez, Grosjean, and Cartajena 2002; Núñez and Santoro 1988; Prates and Perez 2021; Restifo 2013; Rick 1980, 1996; de Souza et al. 2021; Stanish et al. 1997, 2005; Vining et al. 2018). Such observations suggest limited use of the highlands by Paleoindian populations.

On the one hand, the presence of Paleoindian sites in the highlands reveals that the earliest widespread human culture of the Americas—that which produced fluted projectile points—was behaviorally equipped to enter the cold, hypoxic highlands from the get-go or nearly so. On the other hand, the faint signal suggests rather limited occupation, perhaps logistical or seasonal use of the highlands. This may reflect a cultural history that included expansion through tropical environments, including the Isthmus of Panama (Nami 2020), which would have led those populations to shed cultural traditions for living in cold environments, including technologies for cold-weather clothing, shelter, and fire (Garvey 2021).

Despite a sparse archaeological record, the sheer presence of large projectile points demonstrates that large-mammal hunting with projectile technology—likely atlatl technology (Hughes 1998)—was an important component of Paleoindian economies. Given that North and South American fluted points are often associated with Pleistocene megafauna (Mackie and Haas 2021; Prates and Perez 2021), it would seem reasonable to expect the same for the High Andes. Furthermore, the dramatic decrease in projectile point size in the subsequent Early Archaic period when the largest megafauna taxa went extinct is consistent with the hypothesis that fishtail points were associated with large, extinct taxa (Prates, Rivero, and Ivan Perez 2022).

Direct evidence of extinct megafauna exploitation has remained elusive. The highland site of Tibitó in Colombia reveals ostensible lithic artifacts in association with mastadon (*Cuvieronius hyodon*) and American horse (*Equus neogeus*; Correal Urrego 1990). Ostensible stone tools have been reported in association with a giant sloth rib at Pikimachacy cave in northern Peru (MacNeish, Berger, and Protscha 1970). At Cueva Bautista, Capriles and colleagues observe bone that may be associated with extinct megafauna as well as a possible sloth coprolite above a human occupation surface (Capriles et al. 2016a). The highland paleontological site of Casa del Diablo in the Titicaca Basin reveals megafauna dating as late as 12.8 cal. ka (Villavicencio and Werdelin 2018), but evidence of human activity is not reported at the paleontological site. Although unequivocal evidence of human interaction with extinct megafauna is lacking in the Andean highlands, such observations are extremely rare anywhere. The sum of current evidence thus favors a model in which highland fishtail populations exploited Pleistocene megafauna, including extinct taxa.

While projectile points broadly establish large-mammal hunting among highland Paleoindian populations, evidence of other behaviors is lacking. Scrapers, blades, choppers, and burins have been observed in assemblages with fishtail points, but such assemblages—El Inga, Pucuncho, and Salar Punta Negra—all co-occur with Early Archaic assemblages, making confident temporal assignment of nonprojectile tools difficult or impossible. Thermoregulation technologies such as housing, clothing, and fire were likely important, but evidence of those technologies is also lacking.

The antiquity, high mobility, and low population levels of highland Paleoindian groups conspire to create an extremely sparse archaeological record. Synthetic, quantitative analysis of existing finds could marginally advance understanding of Paleoindian land-use patterns and adaptation in the highlands. However, the greater challenge is in locating additional highland Paleoindian assemblages, which are sorely needed to understand the range of activities that took place among the first human populations in the high Andes. Concerted archaeological investigations of Terminal Pleistocene paleontological loci and surrounding areas could help locate related archaeological assemblages. Such needle-in-a-haystack endeavors require both systematic investigation and clever discovery shortcuts such as consulting local agropastoralists who know the land and may have discovered paleontological or Paleoindian remains (Patané Aráoz and Nami 2014). Scholars who take on such efforts should be prepared to report negative results, which are as scientifically helpful as positive results, even if less exciting.

Permanence in the High Andes, 11.7–9.0 cal. ka

In contrast to the faint and geographically restricted Paleoindian signal, the Early Archaic cultural signal is strong and widespread in the highlands. Thousands of Early Archaic projectile points from hundreds of sites have been identified in dozens of systematic surveys (Aldenderfer 1998; Capriles et al. 2018; Cipolla 2005; Grosjean, Núñez, and Cartajena 2005; Haas et al. 2015; Klink 2007; Klink 2005; MacNeish et al. 1983b; Núñez 1980; Núñez, Grosjean, and Cartajena 2002; Núñez and Santoro 1988; Prates, Rivero, and Ivan Perez 2022; Restifo 2013; Rick 1980, 1996; Santoro et al. 2011; de Souza et al. 2021; Vining et al. 2018). These projectile point forms include

triangular, contracting broad-stem, and eared types (figure 2e–o). The strong Early Archaic signal is also evident in well-dated excavations of Early Archaic contexts (Aldenderfer 1998; Capriles et al. 2018; Haas et al. 2020; MacNeish et al. 1983b; Osorio et al. 2011; Rademaker et al. 2016; Rick 1980; Lynch 1980). It is thus clear that human populations had become well established in the highlands sometime during the Early Archaic period.

Whether the Early Archaic adaptive process was gradual or rapid is less clear (Capriles et al. 2016b; Rademaker et al. 2016; Rick 1984; Wheeler 1984). Perhaps the most reliable line of archaeological evidence for assessing the permanence of highland occupation is human bone chemistry. Three individuals from Cuncaicha Rockshelter in the western cordillera of Peru exhibit high-altitude oxygen and strontium signatures consistent with permanent residence of the highlands between 9.0 and 8.5 cal. ka (Chala-Aldana et al. 2017). Eighteen individuals from the sites of Soro Mik'aya Patjxa and Wilamaya Patjxa in the Lake Titicaca region further exhibit high-altitude oxygen and carbon signatures that are consistent with year-round highland occupation between 9.0 and 6.6 cal. ka (Haas et al. 2017 2020). Although these data reliably show that humans permanently inhabited the highlands after 9.0 cal. ka, the lack of isotopic analysis of earlier skeletons limits this interpretation to a *terminus ante quem* estimate. These data are furthermore restricted to the wet puna, and comparable isotopic evidence is currently unavailable for dry puna populations.

A series of other lines of evidence favor a gradual model of highland adaptation. Genetic analyses model the split between lowland and highland populations to have occurred sometime between 10.5 and 8.2 cal. ka (Harris et al. 2018; Lindo et al. 2018). Another genetic analysis of modern and archaeological DNA, including an Early Archaic individual from Lauricocha, finds that selection for high-elevation adaptive alleles transpired over about eight thousand years, suggesting that selection began acting on populations by at least 8 cal. ka (Fehren-Schmitz and Georges 2016). Lithic data show that coastal materials first dropped out of highland assemblages in the Rio Osmore region of the western Cordillera by about 10 cal. ka (Aldenderfer 1998). Finally, securely dated Early Archaic sites of the interior highlands tend to produce late dates (Capriles et al. 2018; Haas et al. 2020), whereas those with earlier dates tend to be located near the highland margins (Aldenderfer 1998; Jolie et al. 2011; Osorio et al. 2011; Rademaker et al. 2014), consistent with a model of slow adaptive process. Currently, then, the sum of evidence suggests that Early Archaic populations had not become permanently established in the highlands until after 10 cal. ka. Moreover, the nature and tempo of highland adaptation likely varied regionally. The current evidence for early permanence is restricted to more northerly, wet puna contexts. In more southerly, dry puna contexts, seasonal transhumance between the highlands and lowlands appears to have persisted throughout the Early Archaic period and beyond (Santoro 1989; Santoro and Núñez 1987).

The current balance of genetic, lithic, and geographic data favors a model of residential tethering to the lowlands prior to 10 cal. ka, and patterns of year-round occupation became gradually established sometime between 10 and 9 cal. ka in the more northerly regions of the Andean highlands. Despite early exploration of the highlands by Paleoindian and Early Archaic cultures, adaptations for more sustained highland occupation appear to have mounted slowly over some three millennia. To be sure, the evidence for this working model remains sparse and indirect.

Strong evidence for permanent highland occupation is restricted to materials postdating 9 cal. ka (Chala-Aldana et al. 2017; Haas et al. 2017 2020). Additional DNA and isotope chemistry analyses of highland human remains, particularly those predating 9 cal. ka, would potentially resolve this question. Replicate genetic and lithic analyses of early assemblages and systematic geographic analysis of early sites are also sorely needed to refine our understanding of the tempo of highland entry.

Early Archaic Adaptation, 11.7–9.0 cal. ka

The behaviors of Early Archaic period highland populations (11.7–9.0 cal. ka) are better understood than those of the preceding Paleoindian populations because of a more complete archaeological record. Evidence for the demographic baseline, thermoregulation technology, subsistence strategies, mobility, health, social organization, and genetic adaptations of the Early Archaic highland populations is summarized here.

Demographic Baseline

Cultural and genetic data for the earliest human populations in and around the highlands allow us to assess the cultural and biological foundations of the first permanent residents of the highlands. The appearance of triangular, contracting broad-stem, and eared projectile point forms (see figure 1e–o) in the highlands after 11.7 cal. ka reflects a clear qualitative shift in cultural systems. Though quite different from their fishtail predecessors, the new contracting stemmed forms are qualitatively similar to Late Paiján forms, which occurred on the northern Pacific coast between 11.2 and 9.6 cal. ka and have a clear morphological affinity with Early Paiján forms that date between 12.8 and 11.2 cal. ka (Maggard 2015). These formal links suggest that Paiján may have laid the cultural foundations for Early Archaic highland populations and that Paiján populations thus were better positioned than Paleoindian populations to occupy the high-elevation niche. If so, the coastally oriented Paiján culture may have benefited from a higher degree of subsistence flexibility than the more terrestrially oriented fluted-point tradition.

The posited cultural replacement in the high Andes after 11.7 cal. ka tracks an apparent biological population replacement. Although the Early Archaic Cuncacha and Lauricocha individuals show broad genetic affinity with North America, they do not show specific affinity with the Anzick-1 Clovis genome, although the Anzick-1 signal appears among earlier individuals elsewhere in South America. These observations suggest a population turnover in South America sometime before 9 cal. ka (Posth et al. 2018, 1192). This broader biological replacement coupled with the changes in projectile point technology would seem to suggest the same replacement process in the Andean highlands, but analysis of Terminal Pleistocene human DNA from highland individuals is required to verify this hypothesis for the Andes.

Early Archaic Thermoregulation Technology

Shelter would have been critical to the adaptive success of early Archaic populations moving into the cold highland environment. Excavation of the Early Archaic levels at Asana revealed postmolds defining ovoid domestic structures with internal hearths, which would have provided heat and light (Aldenderfer 1998). Wall construction is unknown, but the houses at Asana appear to have been substantial and may have utilized animal hides. Wood dowels and pegs in the Early Archaic levels of Guitarrero Cave are consistent with the use of wood pegs to anchor hide walls (Lynch 1980). Bone awls from Early Archaic assemblages at Guitarrero Cave (Lynch 1980), Huachichocana (Fernández Distel 1986), and Telarmachay (Lavallée et al. 1995) further suggest stitched hide technology, which may have been used in shelter construction. The sum of evidence suggests that Early Archaic housing in the highlands consisted of relatively small but substantial conical structures with hide walls and internal hearths for heating and light.

Clothing was likely critical for thermoregulation among early highland populations. Indeed, hide-processing tools are diverse and ubiquitous in Early Archaic assemblages. Scrapers, blades, and hide-burnishing stones are frequent in the Early Archaic levels of Asana (Aldenderfer 1998), Guitarrero Cave (Lynch 1980), Hakenasa (Núñez and Santoro 1988; Osorio et al. 2011), Huachichocana (Fernández Distel 1986), Inca Cueva (Núñez 1992), Pachamachay (Rick 1980), Telarmachay (Lavallée et al. 1995), Tequendama (Correal Urrego 1990), and Tuina-1 (Núñez 1992). A side scraper, end scraper, eared projectile point, and hammerstone were located together in a pit feature securely dated to 9 cal. ka at the site of KCH20 (Capriles et al. 2018). Six scrapers, a projectile point, two bifaces, an ocher nodule, a hide-burnishing stone, and six bone smoothers/awls were observed with an adult burial at Telarmachay dating to sometime between 10.2 and 8.2 cal. ka (Lavallée et al. 1995). Two end scrapers, a side scraper or knife, two blades, flakes, two burnishing stones, and ocher nodules were found with an adult burial at Wilamaya Patjxa, 9.0 cal. ka (Haas et al. 2020; figure 3). Two scrapers and a bone tool covered in red ocher were found in association with an adult burial at Cuncaicha, 8.4 cal. ka (Karakostis et al. 2020). Metacarpal and phalanx muscle attachment morphology of the Cuncaicha individual is consistent with habitual, forceful gripping likely associated with hide working. The consistent association between scrapers and ocher further suggests hide processing given that ethnographic and experimental research shows ocher to be a common and effective hide-tanning agent (Brandt and Weedman Arthur 2002; Rifkin 2011). Bone awls from Early Archaic assemblages at Guitarrero Cave (Lynch 1980), Huachichocana (Fernández Distel 1986), and Telarmachay (Lavallée et al. 1995) are further consistent with stitched hide clothing. The signal for hide processing is thus quite strong in the Early Archaic period and likely relates to the production of clothing and possibly housing covers.

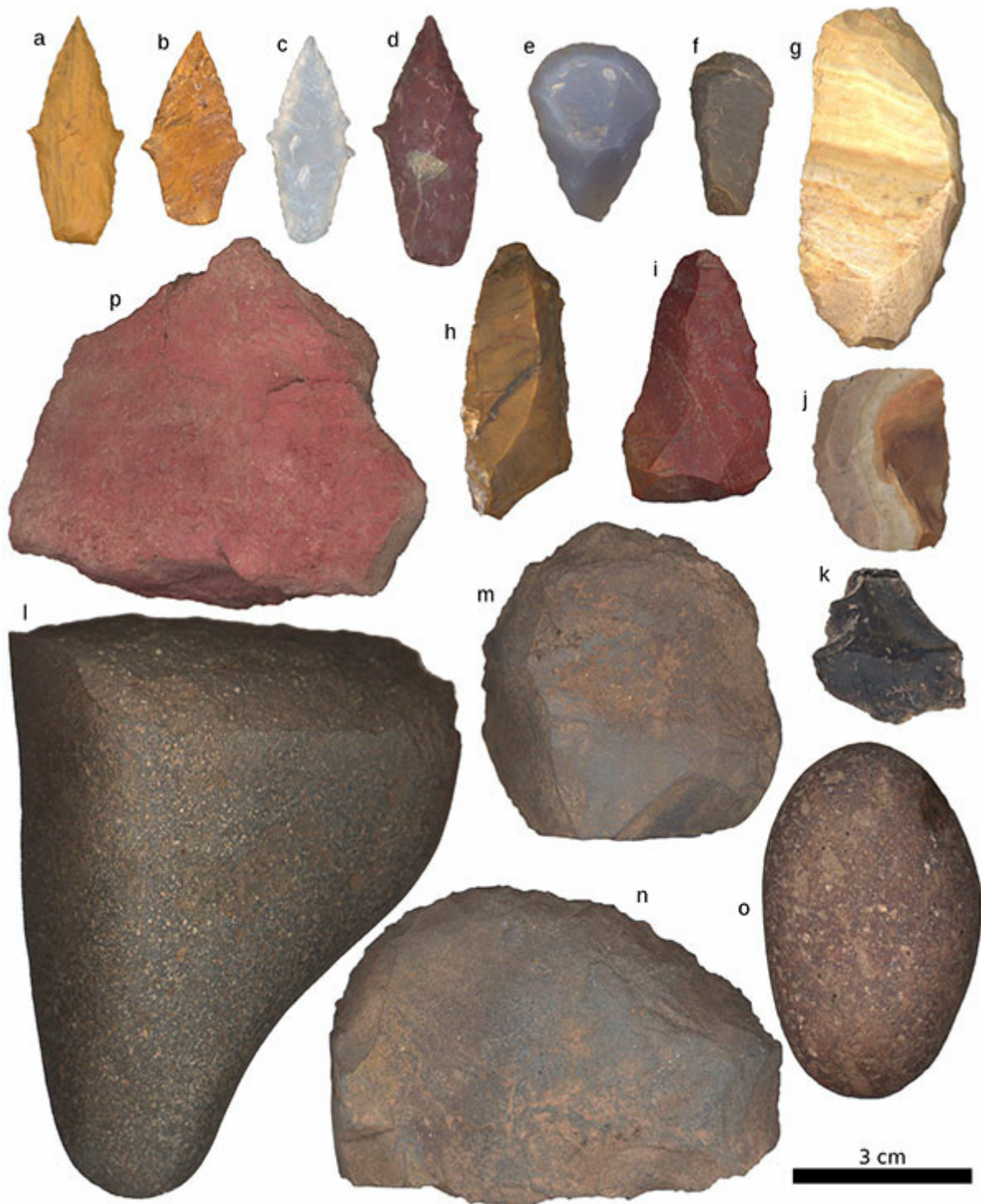


Figure 3. Selection of tools from the toolkit associated with an Early Archaic adult burial at Wilamaya Patjxa. The kit illustrates the range of hunting and processing tools associated with Early Archaic highlanders. (a–d) eared projectile points, (e–f) end scrapers, (g) side scraper or knife, (h–i) blades, (j–k) flakes, (l) red ocher, (m–o) choppers, and (p) burnishing stone. The association of the hunting kit with an adult female further suggests non-gendered subsistence labor.

There are some hints from Guitarrero Cave that plant products may also have been important for thermoregulation during the Early Archaic period. Fragments of close- and open-twined textiles directly date to 11 cal. ka (Jolie et al. 2011; figure 4). The close-twined artifact was made from agave or bromiliad fiber cordage and likely represents either a piece of clothing fragment or bag. The open-twined artifact was made from rush-like stems (e.g., totora) and likely was part of a floor mat—a technology that is commonly used in the highlands for reducing heat loss through ground conduction (Banack, Rondón, and Diaz-Huamanchumo 2004). A fire-drill hearth and fire drill were located in possible Early Archaic contexts (Lynch 1980) and would suggest the use of hand-drill firemaking technology as an adaptive strategy, assuming that the provisional stratigraphic association is reliable.

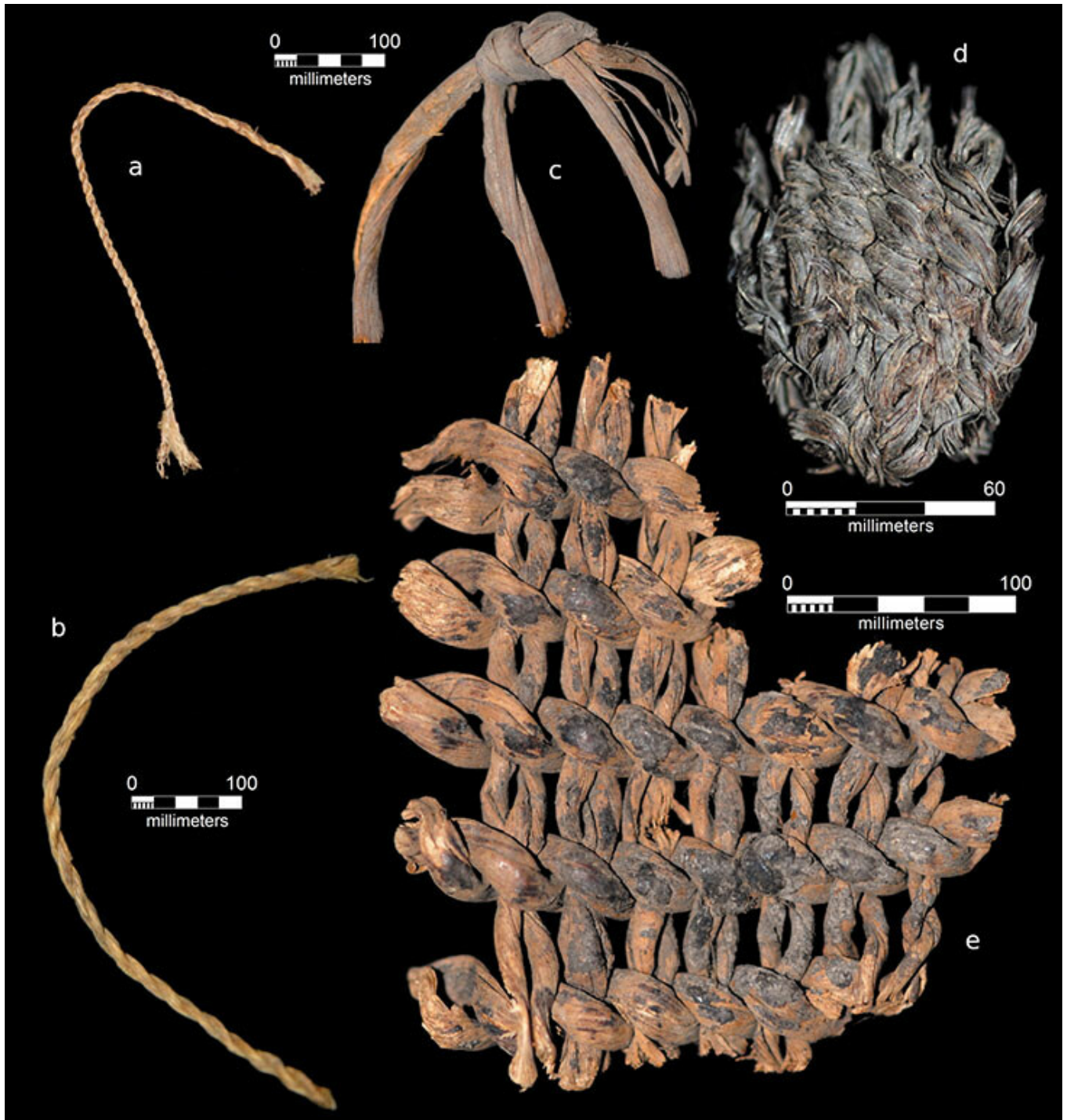


Figure 4. Textile artifacts from Guitarrero Cave directly dated to the Paleoindian and Early Archaic periods (Jolie et al. 2011). The open-weave mat (e) may suggest the importance of bedding technology for thermoregulation, and the closed-weave fragment (d) suggests use of plant-fiber clothing or bags. Image courtesy of Edward Jolie.

These observations demonstrate the central importance of thermoregulatory technologies for high-altitude living in the Early Archaic. However, several questions remain. The specific form of clothing, whether simple robes and capes or more complex tailored leather clothing, remains unknown (Aldenderfer 1998). The current suite of artifacts may simply reflect simple robes analogous to those observed ethnographically among the Selk'am of Tierra del Fuego (Borrero

2001), but tailored clothing cannot be excluded and may even be suggested by the diversity of hide-processing tools in Early Archaic assemblages. Future excavations should remain attentive to relevant perishable artifacts such as eyed bone needles, which are small and difficult to recognize but have been observed in a number of Paleoindian assemblages in North America (Lyman 2015) and Paleolithic assemblages of the Eastern Hemisphere (d'Errico et al. 2018). Additional chronometric and formal analyses of early perishable artifacts such as awls, tent pegs, and textiles from Early Archaic assemblages would be valuable for refining our understanding of thermoregulatory technologies.

Early Archaic Subsistence

The ubiquity of large dart points in the Early Archaic period highlights the importance of large-mammal hunting, presumably with atlatl technology (Chen, Flores-Blanco, and Haas 2021). Further suggesting the importance of large-mammal hunting, camelid and taruca bone have been observed in well-dated Early Archaic contexts at Alero Cuevas (Lopez 2009), Asana (Aldenderfer 1998), Cuncaicha (Rademaker et al. 2014), Guitarrero (Wing 1980), Hakenasa (Osorio et al. 2011), Hornillos 2 (Yacobaccio 2017), Huachichocana (Fernández Distel 1986), Inca Cueva (Yacobaccio 2017), Pachamachay (Rick 1980), Panalauca (Rick and Moore 2012), Quebrada Seca 3 (Mondini and Elkin 2006), and Wilamaya Patjxa (Haas et al. 2020). The abundant large-mammal bones tend to be burned and fragmentary, suggesting intensive marrow and grease extraction (Aldenderfer 1988; Haas et al. 2020; Rick 1980; Rick and Moore 2012). The importance of large-mammal hunting to Early Archaic highlanders is clear. Small-mammal, fish, and bird bone is rare among wet puna sites but is well represented in early assemblages at KCH20 (Capriles et al. 2018), Tuina-1 (Núñez 1992), and a series of sites in northwestern Argentina (Yacobaccio 2017), suggesting more diverse diets among dry puna foragers.

Less clear is the importance of plant foods in Early Archaic diets. The Pachamachay Early Archaic occupation (levels 26–31) yielded relatively low frequencies of edible plant parts, and the most frequent included prickly pear cactus parts (*Opuntia* sp.), chenopodium seeds, amaranth seeds, and plantain seeds (Rick 1980). The Early Archaic level at Huachichocana similarly shows a strong signal of cactus fruit (*Echinopsis atacamensis*) and also identifies passion fruit (*Passiflora* sp.; Fernández Distel 1986). Formal groundstone, which is often associated with plant-food processing, is also exceedingly rare in excavated Early Archaic assemblages (Aldenderfer 1998; Capriles et al. 2018; Haas et al. 2020; Rademaker et al. 2014; Rick 1980; Lynch 1980). Such observations would seem to suggest that plants played a comparatively minor role in economies that depended more on large mammals as an economic staple (Rick 1980; Rick and Moore 2012). However, the bone chemistry of two Early Archaic individuals at Wilamaya Patjxa (c. 10–8 cal. ka) produced depleted stable carbon and nitrogen isotope values that are consistent with a mixed diet in which plant foods were dominant (Haas et al. 2020, SI17–SI18). Additionally, genetic selection at the MGAM locus, which encodes for starch digestion, has been observed in Titicaca Basin populations (Lindo et al. 2018), and selection is estimated to have occurred during the Early Archaic period (Jorgensen et al. 2022). This is further evident in the dental wear patterns of a

Middle/Late Archaic skeletal population dating between 8.0 and 6.5 cal. ka (Watson and Haas 2017). The extent to which this pattern of intensive plant use was in place during the preceding Early Archaic period remains unclear.

The recent convergence of zooarchaeological, paleobotanical, and biomolecular methods is rapidly advancing our understanding of the subsistence strategies of the first Andean highlanders. While our understanding of Early Archaic faunal assemblages is on relatively solid footing, additional paleobotanical studies are sorely needed, particularly those involving flotation-based recovery techniques. Continued analysis of stable isotope bone chemistry will yield a clearer understanding of the relative contributions of plants, animals, and fish to the subsistence economies of the earliest highland populations. Analysis of dental wear patterns could yield insight into the dietary habits of Early Archaic individuals. Finally, experimental foraging studies expanding on those carried out for chenopodium foraging (Kuznar 1993) are needed for tuber foraging to better elucidate its potential role in early adaptive efforts.

Mobility

Although evidence suggests that Early Archaic populations of the wet puna became gradually established in the highlands (Aldenderfer 1998; Chala-Aldana et al. 2017; Haas et al. 2020), initial Early Archaic populations of the wet puna and the Early Archaic populations of the dry puna appear to have occupied the highlands on a seasonal basis (Aldenderfer 1998; Núñez and Santoro 1988; Rademaker et al. 2014). How mobility strategies were organized within the highlands presents a different question. On the one hand, foraging subsistence systems require a high degree of residential mobility to acquire temporally and spatially clustered resources. The lack of ceramic technology, communal architecture, and masonry housing throughout the Early Archaic indicates a high degree of residential mobility. On the other hand, the cold, hypoxic conditions and the territorial habits of vicuña—a major food source—would have compelled a relatively high degree of residential sedentism with resource acquisition via logistical forays (Rick 1980).

Early Archaic residential camps have been observed at Asana and Pachamachay (Aldenderfer 1998; Rick 1980). Lithic assemblages from the dry puna sites of Cueva Bautista, Hakenasa, and KCH20 lack certain components of the lithic production sequence, indicating short-term logistical or seasonal-use camps (Capriles et al. 2016a, 2018; Osorio et al. 2011, 2017). These various observations converge to suggest a mobility pattern somewhere between the extremes of residential and logistical mobility (Binford 1980). In other words, Early Archaic populations were less residentially mobile than earlier Paleoindian populations and more residentially mobile than later agricultural populations that would emerge some five thousand years later. Such mobility patterns would likely have been embedded in a seasonal occupation of the highlands except in the wet puna where Early Archaic populations eventually established land-use patterns entirely within the highlands after 10 cal. ka (Aldenderfer 1998; Chala-Aldana et al. 2017; Haas et al. 2020).

Health

Human skeletal pathology offers insights into the health of Early Archaic populations. An Early/Middle Archaic adult female from Lauricocha (8.8–8.5 cal. ka) showed degenerative joint conditions along with strong muscular attachments (Fehren-Schmitz et al. 2015). Among the three Early/Middle Archaic individuals at Cuncaicha (9.0–8.4 cal. ka), two older adult individuals (30–55 years old, male and female) exhibited bone attrition and osteoarthritis in the ankles, wrists, knees, and spine (Francken et al. 2018). In contrast, a young adult female (18–25 years old) showed negligible signs of pathology. Indications of trauma or malnourishment such as porotic hyperostosis and enamel hyperplasia are absent among the Lauricocha and Cuncaicha individuals. Enamel hyperplasia is also absent in the teeth of two Early Archaic individuals from Wilamaya Patjxa (9.0–8.7 cal. ka), although a young adult (25- to 30-year-old male) exhibited a dental caries and antemortem tooth loss (Haas et al. 2020). Hepatitis B virus was discovered in an Early Archaic individual from Cuncaicha (Kocher et al. 2021). The paucity of pathologies suggests relatively good health, at least at the end of the Early Archaic period.

Social Organization

The absence of communal architecture, prestige goods (e.g., precious metals), food surpluses, and materially rich burials from Early Archaic contexts suggests a relatively egalitarian social structure, which is to be expected among mobile forager populations. Sexual division of labor appears to have been relatively minimal. A young adult female at Wilamaya Patjxa was ceremoniously interred with hunting tools, including five complete projectile points, suggesting that she participated in the hunting of large mammals (Haas et al. 2020). Similarly, an adult female at Telarmachay was associated with a projectile point and two bifaces (Julien, Lavallée, and Dietz 1981; Lavallée et al. 1995). The absence of projectile points among Early Archaic males does not preclude male participation in those tasks given the lack of intact, securely dated male burials from Early Archaic contexts.

Evidence for gendered division in hide-processing labor is unclear. Three securely dated Early Archaic adult females are buried with hide-processing tools at the sites of Cuncaicha (Karakostis et al. 2020), Telarmachay (Julien, Lavallée, and Dietz 1981; Lavallée et al. 1995), and Wilamaya Patjxa (Haas et al. 2020). Furthermore, bone morphology analysis of the Cuncaicha female reveals habitual, forceful gripping likely associated with hide working (Karakostis et al. 2020). Again, although these observations show that females routinely worked hides, the data do not preclude male participation in those tasks given that intact, well-dated Early Archaic male burials are unknown at this time.

Similarly, the extent to which foraging was gendered is unclear but appears to have been minimal. Research at the site of Asana suggests that gendered division of labor may have been a relatively late phenomenon associated with the origins of agropastoralism, suggesting tempered division of labor in the Early Archaic (Aldenderfer 2006b). Dental wear patterns among Middle/Late Archaic foragers show that both males and females processed tubers as early as 7 cal. ka (Watson and Haas 2017), but the extent to which this applies to the Early Archaic is unknown.

The evidence makes fairly clear that Early Archaic social organization was relatively egalitarian. Tentatively, labor practice in the early high Andes, in contrast to that of ethnographic foraging societies, was nongendered (Waguespack 2005). Future isotopic research and morphological analyses of human skeletons are particularly well positioned to assess the questions of inequality and gendered practice in the early high Andes.

Genetic Adaptation

Given that long-term residence of the highlands commenced in the Early Archaic period, selective pressures likely began to induce genetic changes in highland populations beginning sometime between 11.7 and 9.0 cal. ka, likely around 10 cal. ka. The study of high-elevation genetics has identified several adaptive genetic pathways among Andean populations, including those related to the body's response to hypoxia and starch digestion.

The low oxygen levels of the highlands tend to reduce reproductive fitness by lowering work capacity (Baker 1969; Brutsaert et al. 2019) and neonate birth weights (Moore, Charles, and Julian 2011). Genetic selection for regions that encode for respiratory, cardiovascular, or muscular function can theoretically offset the reproductive costs of hypoxia. Relative to lowland populations, contemporary Andean highlanders exhibit elevated residual lung volumes, decreased hypoxic ventilatory sensitivity, and enhanced aerobic capacity at altitude (Beall 2014). Pregnant women and neonates among modern Andean highland populations are less susceptible to hypoxia than lowland populations because of reductions in uterine artery blood flow, which dampens reductions in birth weights (Moore, Charles, and Julian 2011). A number of Andean highland DNA studies find evidence of natural selection at the EGLN1 locus, which is an oxygen sensor locus in the genome that relates to oxygen homeostasis (Beall 2014; Brutsaert et al. 2019; Fehren-Schmitz and Georges 2016).

High genetic differentiation in Andean populations has also been observed in the BRINP3, NOS2, TBX5, and DST genes, all of which are associated with cardiovascular health (Crawford et al. 2017; Fehren-Schmitz and Georges 2016; Lindo et al. 2018). These genetic changes are likely responsible for enlarged right ventricles in modern Andean populations. Andean populations therefore appear to have evolved moderate pulmonary hypertension in response to the selective pressures of the hypoxic environment. Thus, current evidence suggests both respiratory and cardiovascular adaptations to hypoxia. Such genetic changes appear to have occurred after humans moved into the highlands but sometime prior to 8 cal. ka (Fehren-Schmitz and Georges 2016), suggesting that the selective processes commenced with Early Archaic populations. This observation further suggests that some combination of cultural and physiological adaptation allowed for the initial expansion into the highlands with genetic adaptations following (Fehren-Schmitz and Georges 2016).

Epigenetic responses may also have played a role in early high-elevation adaptation. In a study of contemporary Andean populations, paternal highland ancestry was observed to elevate birth weights relative to maternal highland ancestry, suggesting potential epigenetic adaptation (Bennett et al. 2008). DNA methylation—the alternation of gene activity by the addition of methyl

molecules to DNA regions—is observed in association with respiratory and circulatory genes among contemporary Andean highlanders (Childebayeva et al. 2020). These observations suggest an epigenetic pathway to high-elevation adaptation in the Andes, but the extent to which it applied to Early Archaic populations is unknown.

In addition to genetic and epigenetic adaptations to hypoxic conditions, DNA research reveals adaptation to highland subsistence resources. The highest genetic differentiation in skeletal samples dating to 2 cal. ka from the Titicaca Basin was observed in the MGAM region, which suggests selection for enhanced starch digestion capacity (Lindo et al. 2018). This selection event is estimated to have commenced in the Early Archaic period, around 9.5 cal. ka (Jorgensen et al. 2022). A behavioral shift to foraging for underground plant storage organs may have been an effective strategy for extracting calories in a region of low bioproductivity. The ostensible intensification of tuber use appears to have induced a genetic response that entailed enhanced capacity for starch digestion. Dental wear patterns attributed to tuber processing among Middle/Late Archaic foragers in the Titicaca Basin are furthermore consistent with early intensification of tubers as a driver of selection at the MGAM region (Watson and Haas 2017).

Synthesis

The process of peopling the high Andes represents a rare and powerful case study in elucidating human adaptability. The foregoing review suggests that Paleoindian populations of the fishtail fluted-point tradition were likely the first to enter the highlands, around 12.8 cal. ka. However, material and genetic evidence suggests that Paleoindian use of the highlands was relatively ephemeral. Sometime between 11.7 and 9.0 cal. ka, a different population, possibly descended from the coastal Paiján tradition, ascended into the northern highlands and established mobility patterns entirely above 2,500 m in altitude, likely around 10 cal. ka. Important adaptive behaviors identified among that Early Archaic population include heavy investment in hide processing, housing with interior fire hearths, egalitarian social structure, and subsistence diversity with heavy reliance on both large mammals and plant foods. Hide-wall houses, fire-drill technology, tuber foraging, and nongendered labor practice are suggested, but evidence for these behaviors remains equivocal. Genetic adaptations for enhanced respiratory function, cardiovascular strength, and starch digestion also appear to have commenced in the Early Archaic period.

Archaeologists have made remarkable progress in defining a broad outline for a historical process that transpired some thirteen to nine thousand years ago among small, mobile human populations that left few traces on the land. Recent advances in biomolecular methods, especially genetics and stable isotope analysis, have accelerated these advances. Continued investigations at the intersection of traditional fieldwork, macroscale materials analysis, and biomolecular analysis are poised to resolve many outstanding questions about the timing and nature of the peopling of the high Andes. Such investigations will afford a clearer view of the remarkable adaptive history of the first Andean highlanders and the adaptive capacity of the human species more generally.

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