The Dry Puna as an ecological megapatch and the peopling of South America: Technology, mobility, and the development of a late Pleistocene/early Holocene Andean hunter-gatherer tradition in northern Chile

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A B S T R A C T. Current scientific evidence shows that humans colonized South America at least 15,000 years ago, but there are still many unknown aspects of this process, including the major and minor migratory routes involved, and the pattern of successive occupation of a diverse continental mosaic of ecosystems. In this context, the role of the Andean highlands (_3400 meters above sea level) has been neglected, because of the supposedly harsh conditions for humans including hypoxia and cold climate. Nevertheless, the environmental and cultural resources available in the high Andes constitutes an important "megapatch" that should be assessed in terms of human settlement patterns. We review the evidence for late Pleistocene/ early Holocene hunter-gatherer occupation of one part of this megapatch, the northern Chilean Dry Puna, in its palaeoecological context. We focus on lithic technology, faunal remains, radiocarbon dates, and other archaeological materials related to different social activities, which allow us to suggest that groups of hunter-gatherers organized and adapted their way of life to highland ecosystems through logistical mobility, and curatorial strategies for lithic tool kits that included projectile points and other formalized tools. The morphology and technological processes involved are recognized over vast territories along the high Andes. We identify this material expression as the high south central Andean Archaic hunter-gatherer tradition, which also featured long distance mobile settlement systems and communication processes over this broad and distinct megapatch. More speculatively, we outline the hypothesis that these highland ecosystems constituted a suitable migratory route that may have been key for the early peopling of the continent, and contrast it with the alternative hypothesis of the initially secondary and seasonally intermittent exploitation of this habitat by hunter-gatherers dispersing along the Pacific coastal corridor.

1. Introduction

The south central Andean highlands (>2500 metres above sealevel [masl], latitudinal range16-25 deg. S, which encompasses southern Peru, northern Chile and north-western Argentina, Santoro, 1989), like other high altitude environments, are regions with marked ecological gradients where plant and animal communities vary markedly over relatively short distances (Aldenderfer, 1998, 1999, 2006, 2008; Santoro and Nunez, 1987). Ecologically, on the western Andean slope the 2500 masl boundary between the highlands and lowlands generally coincides with dramatic shifts in precipitation that bring about large differences in vegetation and in animal adaptations (Arroyo et al., 1988; Luebert and Pliscoff, 2006). Above 2500 masl, physiological processes related to hypoxia (or decrease in oxygen availability) can affect humans as well as plant and animal populations, due to a reduction in barometric pressure at greater altitudes (Behn et al., 2007; Llanos et al., 2007). Thus, steep relief, low temperatures and hypoxia characterize the ecology of highland landscapes in the following ways: (a) environmental heterogeneity, (b) low predictability (high instability), and (c) low primary productivity (Aldenderfer, 1998). These harsh environmental conditions have led researchers to overlook the Andean highlands as a potential early migratory route and as suitable habitat for the initial human colonization of South America (Bird, 1943; Lanning, 1967; but see Santoro and Nunez, 1987; Santoro, 1989). Archaeological narratives of the region typically begin in the Holocene with Archaic societies, ca. 10,000 years ago (Aldenderfer, 2008).

Recent discoveries of very early sites located in the highlands of Peru (Cuncaincha, at 4400 masl, dated between 12.8 and 11.5 cal. kyr BP; Rademaker et al., 2014) and of Bolivia (Cueva Bautista, at 3900 masl, dated between 12.9 and 12.6 cal. kyr BP; Capriles and Albarracín-Jordan, 2013; Capriles et al., 2016) have challenged this perception of the earliest settlement of the high Andes. Given this new evidence, models of how the highlands were peopled are also being r-evaluated. One proposal which we advance here relates to whether this whole high south central Andean sierra/dry puna region represented an ecological high Andes ‘megapatch’ (a term introduced by Beaton, 1991) with a dispersed but interconnected hunter-gatherer settlement system extending as far north as the highland of the Peruvian Central Andes (where comparable biomes are found in the Pampa de Junin, 11 deg S, the punas of Ancash, 8-9 deg S, and the Cajamara puna, 7 deg S; K. Rademaker, pers. comm.). Another ongoing debate relates to the possibility of a late Pleistocene dispersal corridor across this predominantly north-south oriented South America megapatch, accompanying the Pacific coastal corridor hypothesis that is a familiar element of initial colonization models (Sandweiss, 2008). Validation of the Andean megapatch would not, in itself, prove its use as an initial dispersal corridor. However, validation of the initial dispersal corridor hypothesis would necessarily support the megapatch hypothesis, since part of the definition of a dispersal corridor is that it represents a continuous area of exploitable habitat.

In this paper, we discuss evidence from the five earliest known archaeological sites in the highlands of northernmost Chile at the South Central Andes, which date to the terminal Pleistocene/early Holocene (ca. 12.0-9.5 cal kyr BP) (Fig. 1). In introducing these sites into the discussion of the role of early high altitude settlement in the peopling of South America, we propose also to explore the first of the above two hypotheses, namely that the Andean highlands may have constituted an important megapatch and that the material culture of these sites was part of a region-wide cultural tradition and settlement system. This paper thus complements previous work regarding specific mobility strategies engaged by early hunter-gatherers in northern Chile (Osorio et al., 2017).

1.1. The south central Andean dry puna as a megapatch

We suggest that the south central Andean high puna can be considered a megapatch, as defined by Beaton (1991). Beaton derived the concept from the patch choice model in classical foraging theory (e.g. Pyke et al., 1997), where it complements the diet-breadth model by predicting how movement by foragers will occur between circumscribed areas with specific resources (patches). On a larger spatial scale, regions with a resource structure distributed across many rather homogeneous patches, but which appear, in a coarser grain, homogeneous in relation to a given cultural tradition of resource exploitation can be considered as 'megapatches'. This notion differs somewhat from the ecological concepts of 'biomes' (plant and animal communities determined by climate) and 'ecoregions' (geographically continuous instances of particular biome types), by being additionally defined with relation to a specific set of human foraging goals. It has significance in two distinct contexts here: firstly, in enabling us to predict that an ecosystem such as the high Andean puna may have supported a widespread tradition of hunter-gatherer adaptation after initial occupation; and secondly, in enabling us to speculate that such an ecosystem, with its predominant North-South axis, may also have facilitated dispersal and range expansion.

Beaton's own focus (1991:220) was on the colonization of continents, and he only loosely identified several possible types of megapatch: "coasts, mountains, plains, forests, deserts, riverine courses, etc." He also suggested that colonization would typically first occur in 'preferred habitats' such as coasts and river valleys, only later expanding into other kinds of habitat that required significant new adaptations. Others have subsequently emphasized that during range expansion, knowledge acquired locally by hunter-gatherers about animal and plant characteristics could have been transferred to unfamiliar landscapes within a megapatch, minimizing the demands for landscape learning (Kelly, 2003; Meltzer, 2003; Rockman, 2003). Confining movement within megapatches, therefore, would have allowed successful and more or less continuous dispersal (Borrero, 2015). Examples of them which have been explicitly identified as such by other authors in the context of early peopling of the Americas include: the Pacific rim coastal corridor (e.g. the Kelp Highway hypothesis, Erlandson et al., 2007), the Great Plains and other regional biomes of North America (Meltzer, 2004), eco-refugia of North American megafauna linked to terminal Pleistocene climatic stress (Haynes, 2013), and in the southern cone of South America, the xeric steppe and the temperate evergreen forests of Patagonia (Borrero, 2005).

For the South Central Andes and their western coastal margins, an influential hypothesis asserts that initial dispersal followed the coastal corridor, with subsequent expansion into high altitude ecoregions - initially on an intermittent or seasonal basis (Aldenderfer, 1998; Sandweiss, 2008). The first half of this argument has been seen as supported by radiocarbon evidence for a lag in radiocarbon ages for early sites in the montane as compared with the coastal regions (Aldenderfer, 1998; Sandweiss et al., 1998). This has then led to the expectation that initial expansion into high altitudes would have been for occasional, or at most seasonal, hunting expeditions. Aldenderfer (1999/2000: 85), for example, suggests that in mountain environments. "Mobility should be logistical in form, with relatively few residential moves on an annual or seasonal basis. In temperate mountain environments, high-elevation land use will be limited to the late spring through early fall months since temperature and climate are too extreme for permanent habitation. Foragers will move to lower-elevation base camps during the winter. High elevation land use during the late spring through early fall will be characterized by some residential mobility as foraging groups move into the highlands to exploit newly-available resources. The degree of residential mobility will depend on specific resource configurations, while the size of the foraging group and whether or not it disperses into smaller units depends on resource density, abundance, and distribution." Aldenderfer (1999/2000) also suggests that the archaeological record points to a fairly rapid adaptive shift to permanent occupation of Andean high altitude environments within 500 years of initial exploration, with the coastal ecosystems subsequently no longer included in these montane foragers' annual subsistence circuits. An implication would then be that this also marked a shift from exploitation of ecologically complementary zones by seasonal mobility, to one involving more complex kinds of social alliance and exchange, that enabled all groups to develop more fin-grained local adaptations. This change should have been reflected in a more permanent occupation of the highlands, with the localisation of residential camps near high-quality resource patches, to increase the efficiency of the subsistence effort of these hunter gatherer groups (Aldenderfer, 1998).

In considering the macro-regional similarities in the technology among the early Andean hunter-gatherer sites, we therefore propose that adaptation to the permanent occupation of the highlands can be most easily reconstructed by focusing on sociocultural traditions found within the highland region itself. The coast and the lowlands remained interconnected but socioculturally distinct. We propose that archaeological correlates of long-term adaptation to a megapatch must include not just evidence for its permanent occupation, but also evidence for a focus on particular resources coupled with the necessary technological strategies for resource acquisition and processing. We expect that such a strategy is likely to lead to some degree of mapping of the demographic structure of hunter-gatherer populations onto the mega-patch and its boundaries, such that there is also likely to be homogenization of cultural traditions and social systems. In contrast, we do not expect that occupation of a megapatch should always correlate with a consistent pattern of lithic raw material procurement, nor with a consistent preference for campsite location at specific kinds of landscape features (e.g. rock shelters vs. open air sites), because raw material and natural shelter availability will also be affected by physical and chemical variation in bedrock and surficial geology.

2. Regional environmental characteristics, past and present

The Andean orographic effect creates severe environmental conditions for human activities across the steep relief that rises abruptly from the Pacific coast to the Altiplano. Atmospheric pressure drops logarithmically with altitude (West, 2004) and temperature decreases at a predictable rate of 0.0065 _C/m (Petersen and Pellicciotti, 2011). Conversely, the rain-shadow imposed by high Andean ridges to humidity from eastern South America (Garreaud et al., 2003; Vuille and Keimig, 2004) creates a strong gradient that ranges from semi-arid conditions >5000 masl (~300 mm/yr), to arid conditions at 4000 masl (<100 mm/yr) and finally to hyperarid conditions (<5 mm/yr) below 2500 masl (Houston and Hartley, 2003).

Prevailing cold-xeric conditions constrain the presence of any glaciers to the highest ridges (>5000 masl, Amman et al., 2001) and hillslope vegetation grows at elevations above 2500 masl up to 5000 masl (Gajardo,1994; Arroyo et al.,1988). Indeed, following the elevation, rainfall, and temperature gradients, primary productivity peaks at mid-elevations (3300-4000 masl), and declines as aridity (or adiabatic cooling) increases at lower (or higher) elevations (Villagr_an et al., 1983; Arroyo et al., 1988). Localized groundwater and superficial discharges sustain dense and highly productive Andean peat-bogs (*bofedales*) between 3400 and 5000 masl (Squeo et al., 2006). These peat-accumulating wetlands have provided key ecosystem services by sourcing fresh-water, fuel supply, wild faunal resources (i.e. birds and small rodents) and grazing habitats for domestic and wild herds (Squeo et al., 2006; Patty et al., 2010; Salvador et al., 2014).

Aridity and extreme minimum temperatures at high elevations are exacerbated south of 20 deg S, defining the transition between the wetter-temperate Dry Puna (16-20 deg S) and the cold-drier Salt Puna (20-25 deg S) eco-regions (Troll, 1958; Santoro and Nunez, 1987). Tussock grasses associated with cushion-plants and sparse shrubs prevail in both eco-regions. Nevertheless, these differ considerably in species composition and ecosystem properties. Grassland and steppe bioproductivity as well as the extent of *bofedales* are greater in the Dry Puna (Villagr_an et al., 1983; Arroyo et al., 1988; Nunez and Santoro, 1988). Although edible fruits are lacking, the Dry Puna has constituted a favourable productive environment for permanent human settlements at elevations >4000 masl. Today, existing high-elevation households are occupied year-round, with reliance on agriculture activities as high as 4000 masl and camelid pastoralism complemented by seasonal herd mobility to lower elevations in the late austral summer and fall (Nú~nez and Santoro, 1988).

The western Andean slope underwent two protracted positive hydroclimate anomalies (Fig. 2) at 18.1-14.1 cal kyr BP and 13.8-9.7 cal kyr BP as hydrological budgets increased over a vast area of the south central Andes (16-25 deg S) at the end of the last glacial period. Together, these millennial-scale variations in the regional hydrological cycle are part of the Central Andean Pluvial Event (CAPE I and CAPE II, Latorre et al., 2006; Quade et al., 2008; Placzek et al., 2009; Gayo et al., 2012; further investigation should reveal the extent of any spatially lagged responses and/or differential sensitivity of local circulation patterns to these disruptions in the Andean climate system).

Substantial evidence indicates that the CAPE stages profoundly affected the potential for early hunter-gatherer settlement by increasing the availability of hydrological and biotic resources across the arid Andes (Moreno et al., 2009; Santoro et al., 2011; Gayo et al., 2012; Latorre et al., 2013). For instance, wetter conditions led to a prominent lacustrine transgression on the Uyuni basin (Placzek et al., 2006, 2013; Blard et al., 2011) and other minor high-elevation basins (Geyh et al., 1999; Grosjean et al., 2001; Bao et al., 2015) during the Tauca (18.1-14.1 cal kyr BP) and Coipasa (12.8-11 cal kyr BP) lake highstands. Concomitant glacier advances, implying a snowline depression of up to 1000 m, occurred on the Bolivian Altiplano apparently brought about by a precipitation intensification of at least 250 mm/yr and >4 deg C cooling (Blard et al., 2009, 2013; Placzek et al., 2013). Similarly, positive rainfall anomalies enhanced groundwater and superficial discharge along Andean catchments (Rech et al., 2003; Nester et al., 2007; Quade et al., 2008; Gayo et al., 2012; Schittek, 2014; Saez et al., 2016; Veit et al., 2016), which in turn could have amplified the extension and bioproductivity of fertile environments for human activities (i.e. *bofedales*).

Moreover, moister conditions promoted significant increases in the availability of plant resources for livestock at lower elevations as evinced by elevational displacements of hillslope vegetation and reconstructed plant-cover for Andean grasslands (Maldonado et al., 2005; Latorre et al., 2006; Quade et al., 2008; Placzek et al., 2009; Mujica et al., 2015).

3. Archaeological evidence for early occupation of the Dry Puna: the north Chilean case

We now review the archaeological record of early human settlements of the Andean highlands, focusing on the Dry Puna of northern Chile. We define the technological features of the lithic assemblages, complemented with descriptions of other components found in the camps such as faunal remains and ochre pigments. Our megapatch model predicts the development of a cultural tradition with consistent attributes within a fairly homogeneous resource zone.

Our case study includes the five earliest sites that have been found in the Dry Puna of northern Chile, located between 3100 and 4500 masl, in the Arica and Parinacota Region (18-19 deg S). These sites are Las Cuevas, Hakenasa, Patapatane, Pampa El Muerto 15, and Ipilla 2 (Fig. 1, Table 1), We have analyzed material from the earliest stratigraphic levels of these sites, which are dated to the Pleistocen-Holocene transition (ca. 11.5-9.0 cal kyr BP). The five sites presented here can be split into three groups: the oldest sites located above 4000 m (Las Cuevas and Hakenasa) were occupied during CAPE II, whereas the younger sites are located below 4000m(Patapatane, Ipilla 2) and postdate the CAPE II event (Fig. 2). The third group composed by Pampa El Muerto 15 falls in between these upper and lower elevation sites and is intermediate in age (10.7 cal kyr BP). Previous studies on these and other Andean sites focused on lithic technology and faunal assemblages, which were then used to discuss mobility strategies using classic models such as transhumance, cyclical mobility, and sedentism, or newer behaviorist approaches (Niemeyer and Schiappacasse, 1963; Cardich, 1964; Lynch, 1971; Rick, 1980; Santoro and Nunez, 1987; Aldenderfer, 1998; Osorio et al., 2017).

The total study sample, obtained from the earliest levels of these five sites, is composed by 3848 fragments of faunal remains and 4446 specimens of lithic artifacts (Table 2). For bone assemblages we used standard zooarchaeological techniques and classified the material to the highest taxonomic and anatomical resolution that their condition permitted (Lyman, 1994; Reitz and Wing, 2008). Cultural and non-cultural modifications were also recorded. Lithic technological analyses included both the debitage and the tools (defined by the presence of retouch or of used edges), with a main focus on identifying reduction sequences (Andrefsky, 2005, 2008; Aschero and Hocsman, 2004). The highest-level descriptive variables recorded were raw material, type and size of debitage, presence of cortex, and type of platform. We also classified sites by function (residential or logistical, Binford, 1979, 1980; Nelson,1991) and by technological strategy (Bamforth, 1986; Nelson, 1991; Shott, 1996), using the criteria of Binford (1979, 1980), Nelson (1991), and Aldenderfer (1998). The presence of logistical sites would allow us to define a collector mobility strategy, which differs (along a continuum) from the forager mobility strategy. The main difference between the two is that in a forager system, hunter-gatherers maintain high residential mobility (movement of the complete group from one camp to another) with fewer logistical movements (movement of specific task groups out from the camp that then come back), whereas in a collector system, hunter-gatherers make fewer residential movements and invest more effort in logistical forays (Kelly, 1995).

3.1. Faunal assemblages

The faunal assemblages were dominated by artiodactyls, especially camelids (guanaco and vicuna), in all five sites (see Osorio et al., 2017). Also present were a few deer bones (probably *Hippocamelus antisensis*) at Hakenasa. Other identified taxa include medium-sized rodents such as vizcachas (*Lagidium*), wild guinea pig (*Cavia*) and cholulos (*Ctenomys*, a small Andean mammal similar to the North American gopher in its burrowing habit). Many bones are burnt or have breakage patterns consistent with human consumption (Supplementary Information, Fig. S1).

Birds were also present, and although they were not identified to genus, most correspond to medium-sized ducks and coots. Exotic faunal remains are very scarce; for example, two shark teeth were identified in Las Cuevas and Ipilla 2, and unidentified fish bones from the Pacific Ocean and mussel shell (*Choromitylus*) fragments (three of which show evidence of edge retouch) were found in Patapatane.

3.2. The lithic assemblages (see also Osorio et al., 2011; Herrera et al., 2015; Santoro et al., 2016; Osorio et al., 2016)

A large variety of lithic raw materials were recorded and can be grouped into five general categories (siliceous rocks, obsidian, basalt, sandstone and other rocks) with a predominance of high quality siliceous rocks. The siliceous rocks found in the two oldest and highest sites, Las Cuevas (11.5 cal kyr BP) and Hakenasa (10.9-11.3 cal kyr BP) must have been transported from lower elevations, which required journeys of at least 30 to 40 km. The younger sites (Pampa El Muerto 15, 10.7 cal kyr BP; Ipilla 2, 10-9.4 cal kyr BP, and to a lesser degree Patapatane, 9.4-9.0 cal kyr BP), are located close to seasonal watercourses where nodules of siliceous rocks adequate for knapping are readily available (Table 3).

Obsidian, which is abundant in Hakenasa and Las Cuevas, was probably transported from the relatively close Chara~na and Parinacota sources, both of which are currently under study by our research group. Small nodules (<5 cm) mixed-in with surface gravels and consistent with the size of artifacts are common near these sites, and occur throughout the Altiplano. In contrast, obsidian is exotic at the three younger sites, where it is also infrequent in the lithic assemblages.

Debitage dominates the lithic assemblages (~98%) and mostly derives from late, and to a lesser extent, middle stages of reduction of mainly bifacial and in less degree unifacial tools. Most of the observed debitage (Table 4) is characterized by the absence of cortex (81-98%), small size (<20 mm), and a preponderance of broken, reduced and flat platforms (Inizan et al., 1999; Duran and Soler, 2006). We also found bifacial trimming flakes with faceted or “complex” platforms, lips, flake curvatures, and dorsal scars in different directions (Andrefsky, 2005) (Fig. 3). We also found some evidence of probable heat treatment in some of the siliceous debitage in Hakenasa, and we found small fragments of red pigment at Las Cuevas and Patapatane.

Together, these attributes and the absence of complete cores suggest that the activities consisted primarily of shaping and reactivating instruments, and secondarily of bifacial reduction. Only four fragments of exhausted cores were observed in Hakenasa. The lithic debitage from Patapatane and Ipilla 2 mainly corresponds to retouching debitage and, to a lesser extent, to flakes and other fragments. Most of the lithic debitage does not include cortex (Fig. 4) and is of small size (<20 mm). These features are also indicative of the final stages of the reduction sequence. Most of the lithic tools were highly standardized and maintained, which is consistent with the high frequency of retouching flakes recorded (Fig. 4). Projectile points are the most frequently observed instrument, but they are only present in three of the studied sites (Patapatane, Hakenasa and Ipilla 2), and correspond to five morphological types: stemmed with shoulders (known as Patapatane); triangular with either straight, convex or concave base; and tetragonal. Many of these projectile points have evidence of maintenance by r-sharpening of the edges, and some of them show evidence of recycling (Osorio et al., 2011; Herrera et al., 2015). At Patapatane and Hakenasa, projectile point preforms and abundant debitage are also present, all indicative of final stage manufacturing processes.

Side scrapers are the most abundant tool at Hakenasa: their forms are simple or double convex and show high standardization and maintenance. Scrapers (semidiscoidal and end scrapers) are very common and highly maintained. In lower frequencies we found hammers at Patapatane and Ipilla 2, and small core fragments in Hakenasa. Unstandardized or expedient tools are extremely rare, and correspond to utilized flakes in Ipilla 2 and retouched flakes in Pampa El Muerto 15. The latter site also includes one notched tool, possibly related to processing plants (Winchkler, 2006; Hocsman, 2009; Osorio et al., 2016).

In terms of site function, some formal tools at Hakenasa show macroscopic wear traces on their active edges and were possibly used for hunting animals as well as processing hides and meat. The frequency of projectile points, scrapers, side scrapers and knives, suggest animal procurement and meat and hide (and to a lesser extent, plant) processing activities, which is consistent with the abundant faunal remains, especially camelids, found in association with the stone tool assemblages.

Similarly, at Las Cuevas we recognized a predominance of final stages of formalization, r-sharpening of worn edges and to a lesser extent, bifacial knapping. The instruments are scarce and suggest activities related to scraping and to tool maintenance. At Ipilla 2, the predominance of medium and mostly final stages of reduction, especially of bifacial artifacts, as well as knives and side scrapers, indicate diverse activities such as hunting, animal processing, and probably leather scraping. There are also a few expediently utilized flakes (with macroscopic wear traces), and a denticulate scraper possibly used in woodwork. At Pampa El Muerto 15, the site with the most ephemeral occupation, knapping activities, shown by instruments and debitage were rare, and were related to final stages of tool manufacture, and to cutting and processing meat and other soft materials such as plants.

3. Discussion

3.1. Interpretation of site function

We interpret the analysed sites as temporary logistical camps (Binford, 1980) as suggested by the quantity and characteristics of the lithic assemblages, which were focussed on final stages of lithic reduction sequences for formalization or reactivation of worn edges, and by the absence of more elaborated features like hearths. The almost exclusive use of high quality raw materials, the small size of the tools, their standardized forms, and the changes in their morphologies due to rejuvenation, are all attributes of a curatorial strategy. The tools recorded in the five studied sites were transported by hunter-gatherers in their mobility circuits and were not initially elaborated in situ. The identification of bifacial trimming flakes shows bifacial reduction, which is also an element of a curated system, reflecting those tools' flexibility and transportability (Shott, 1986; Kelly, 1988). In this way, hunter-gatherers anticipated, mitigated, and minimized risks of possible adverse conditions, like the absence of good raw materials, or insufficient time for manufacturing tools at moments where they needed them (Nelson, 1991). The specific strategy for facing these difficulties is to invest more energy in the manufacturing of the artefacts, and the transportation of a toolkit elaborated in advance.

Risk minimisation, a crucial element in the process of colonization of new landscapes (Meltzer, 2003) has been especially emphasized by Aldenderfer (1998) for the early occupation of a mountain environment. Due to the extreme conditions of the highland ecosystem (low temperatures and hypoxia), hunter gatherer decision-making would have been guided by the need to reduce effort in obtaining a sufficient caloric return (Aldenderfer, 1998, 1999). In the scenario of an early first entry into highland zones, curation and versatility of the tool kit would have been an essential strategy for an effective settlement process.

The two earlier sites located >4000 m in the Dry Puna (Las Cuevas and Hakenasa) are both interpreted as logistical camps. Las Cuevas has a briefer occupation with minimal processing of formalized instruments, and could be related to the initial phase of exploration of new areas. The absence of projectile points may indicate that hunting activities were carried out elsewhere. Hakenasa Cave, some 35 km away, has evidence of multiple activities (hunting, processing of animals, and final manufacturing of the instruments).

The second and later group of sites, Papatapane and Ipilla 2, show striking similarities, including final stages of the lithic reduction sequence. The difference with the earliest sites, however, is the presence of more diverse activities, especially in Patapatane (hunting, scraping, processing animals, among others). Such diversity could be due to either longer stays at the sites, or to frequent visits to the site over a short time period (the two earliest ^{14}C dates from Patapane, Beta-238852 and I-12837 are statistically indistinguishable by Ward & Wilson's test, $p > 0.05$, T=0.64, X2=3.84).

The appearance of some exotic materials in Las Cuevas (shark teeth) and Patapatane (fish bones and shells) suggests the existence of inter-regional exchange with other groups. Such exotic elements can contribute to identifying interaction between different bands, or social differentiation within groups (Castillo and Sepúlveda, 2017). Additionally, the presence of probable bone beads in Hakenasa and red pigments in Las Cuevas are key indicators of social activities that went beyond hunting and procurement of raw materials. Indeed, the absence of a specific theoretical framework for early colonizing strategies that can predict the use of such “rare” materials, reveals the over-simplification of explanations for early hunter-gatherer societies which focus solely on economic and technological aspects (Miotti, 2003). In more recent times, although only one piece of painted rock has been identified for the late Archaic Period in Patapatane, rock art of a naturalistic tradition can be encountered, without major stylistic changes, from the end of middle Archaic (6.7 cal kyr BP) up to the Formative periods (ca. 1.3 cal kyr BP) in the region (Sepúlveda et al., 2017). This tradition is shared by the highlands of the southern Peru and northernmost Chile (Sepúlveda et al., 2013), demonstrating a flow of information between hunter-gatherer groups at a large spatial scale and the creation of territories with specific symbolic landmarks. Economic intensification and social complexity created cultural landscape linked to a naturalistic rock art tradition, which is coincident with specific territories in the Dry Puna megapatch. This traditional symbolic practice stemmed from a long-term history of hunter gatherer adaptation inside this high Andean region.

3.2. Wider cultural relationships and implications for the Dry Puna megapatch model

To further evaluate the earliest evidence for such large-scale interactions, we looked at the lithic record in wider comparative perspective within the south central Andean highlands. We note remarkable similarities among formal tool types present at Hakenasa, Patapatane, and Ipilla 2 (all dated to 11.3-9.5 cal kyr BP), and at sites located in the Peruvian highlands (~12.8-9.0 cal kyr BP). For instance, the triangular unstemmed projectile points found in Hakenasa and Patapatane (Fig. 5: 1, 19, 20) are also found in the earliest levels at Pachamachay (Rick, 1980). However, the most common element shared between the sites from northernmost Chile and the assemblages of other early Andean highland sites is the stemmed point with shoulders known as a “Patapatane” projectile point type (Fig. 5: 1,19, 20; Santoro,1989; Osorio et al., 2011). Its morphology is similar to the point Type 1A, defined by Klink and Aldenderfer (2005) at Asana and Caru (Ravines, 1967; Aldenderfer, 1998). Similar point shapes occur at Telarmachay (Lavallee et al., 1995), Pachamachay (Rick, 1980), Lauricocha (Cardich, 1958), and Guitarrero Complex 2 (Lynch, 1980) in the central Peruvian Andes (see Fig. 5). The similarities are identified mainly in the morphology of the stems, and the maintenance of shoulders or barbs even when the projectile points were reactivated. It seems possible to identify a change in shape with use: probably the projectile point initially had barbs, which would have changed to shoulders because of the reactivation process (cf. Hoffman, 1985; Shott and Ballenger, 2007). Additionally, the overall geometry also changed, moving from convex edges and more elongated blades, to straight edges and shorter blades, producing a triangular morphology (Fig. 5: 11, 13, 14).

Stylistic similarities in projectile point form, when defined by a diagnostic morphology and technology of production that represents more than archaeologists' essentializing of a midpoint on some continuum, may arise and persist by repeated and conservative cultural transmission within social networks or groups. These distinctive characteristics may arise and persist simply through cultural drift due to partial population isolation, or they may be maintained as active signals of social identity (Close, 1978; Meltzer, 1981; Sackett, 1982; Wiessner, 1983; Wobst, 1999). The Patapatane type is therefore informative as a cultural tradition and potentially as a symbolic resource, which indicates the existence of wider networks of social relations between dispersed and highly mobile groups involved in different kinds and scales of social interaction and exchange (and as a minimum, the transfer of knowledgeable people between local bands). If an active signalling function is assigned to the Patapatane type, then this must have extended beyond the smaller-scale 'intimate networks' of local bands where the presence of such symbolic or stylistic resources was not necessary (Gamble, 1998). By implication, the use of a specific type of lithic projectile point was not only a simple tool for hunting, but also a communication device spread over the central Peruvian and south central Andean highland megapatch. This signalling of cultural identity would also formed part of the background for other later communication practices shared across the south central Andean highland megapatch, such as the rock art (already noted above), which show similarities in the represented figures, in its formal and technical features and in the composition of the panels (Sepúlveda et al., 2013, 2017).

4. Conclusions

The evidence described and analysed here suggests that the highland sites from northernmost Chile were camps occupied within a logistic mobility system, and coupled with a curatorial tool strategy. The associated residential camps have yet to be found, if indeed they existed at the same elevations in the high Andes. However, we are inclined to suggest that our understanding of the diagnostic signatures of such camps during an initial occupational phase should also be re-evaluated and new models proposed, especially for interpreting differences in lithic assemblages and implied activity patterns at camps that are not captured by the simple dichotomy of residential and logistic. Indeed, it is possible that the evidence discussed in this paper, which spans a 2000-year time range, reflects neither an initial exploration phase (Borrero, 1989/90) engaged in by transient explorers (Beaton, 1991), nor intermittent hunting expeditions to a familiar but physically difficult environment from base camps at lower elevations. Instead, it could reflect a highland way of life that had developed over generations of permanent occupation within this large megapatch.

Resolving these competing interpretations will require further information on lithic raw material procurement (to establish at which elevation zone the raw materials had been procured), the identification of contemporaneous residential camps of the same cultural tradition, and further information on resource availability and seasonality during the earliest occupation phase in CAPE II. We further note that there are as yet no dated occupations in the Andean highlands (or in all of the central Andes) that date to the CAPE I event, despite abundant evidence for increased available moisture. One possibility is that temperatures may have been simply too cold for human occupation, but this should be tested by seeking new evidence.

Turning more speculatively to the potential of the Andean highlands as a migratory route, we have argued that the highlands of southern Peru and northernmost Chile, which correspond to geographical distribution of the Dry Puna, constitute a rather homogeneous "megapatch" that may have favoured rapid dispersal from north to south (after initial discovery by hunter-gatherers dispersing inland as well as southwards along the Pacific coast). It may also potentially have provided a habitat 'bridge' to the eastern side of the Andean mountains. Specific ecological conditions during the Pleistocene-Holocene transition may have favoured human occupation of the area, and recent discoveries in the highlands of Peru and Bolivia show that parties of hunter-gatherers initiated processes of colonization at much earlier stages than was previously thought. However, resolving the chronology of initial occupation of the South Central Andes and its different altitudinal ecozones, for comparison with the chronology of settlement of the lowlands and coastal margins, will require additional radiocarbon dates from a larger sample of sites.

We propose that the longevity and distinctiveness of the hunter gatherer Andean tradition we see in the Dry Puna megapatch indicates long-term familiarity with and cultural adaptation to the highland landscapes and ecosystem, consistent with permanent occupation (Rick, 1980). The existence of shared ideas and of long distance communication processes may reflect the development of a cultural tradition linked to occupying and appropriating this particular megapatch.

Finally, we contend that the megapatch concept is a useful tool for the analysis of settlement processes on a broad spatial scale (Dixon, 2001), such as the early occupation of South America. We suggest that the ecological and geographical boundaries of the Dry Puna megapatch are reflected in similarities in lithic technology and typology at the sites reviewed in this paper. By contrast, the archaeological records of the Atacama Desert and the Salt Puna, south of the Dry Puna, are completely different in their cultural trajectory, in their lithic assemblages (different technology and projectile point types), and in their paleoenvironmental conditions, which did not favour year-round human occupations (Santoro and Nunez, 1987; Santoro, 1989; Nunez et al., 2005; Osorio et al., 2017). The next step in developing this approach is to specify in greater detail the distinctive cultural traits and the defining ecological characteristics of this Late Pleistocene-Early Holocene Andean megapatch. Furthermore, this zone may not be completely homogeneous: its archaeological variability must also be further explored.

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Fig. 1. High Andes Central Peru and Dry Puna Pleistocen-Holocene archaeological sites.

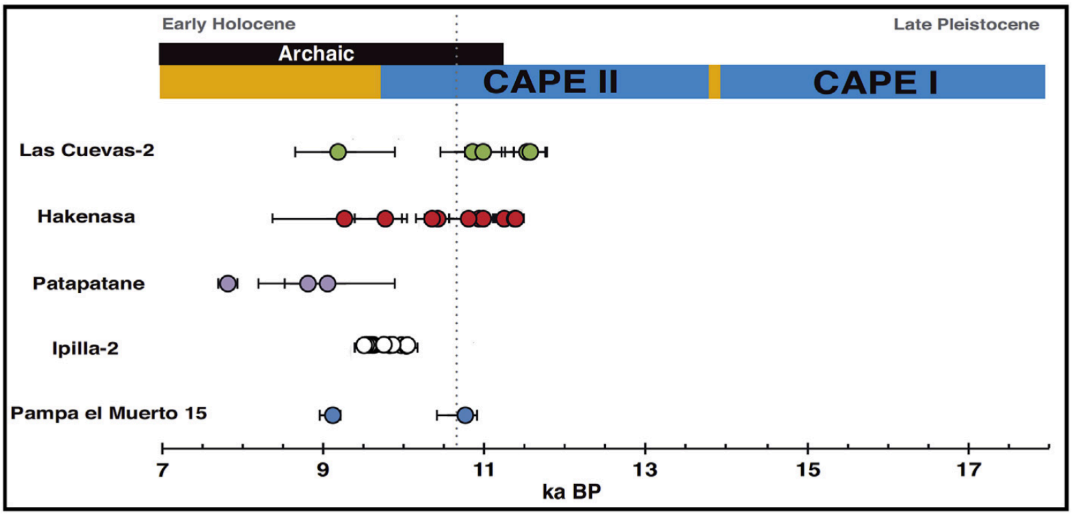

Fig. 2. Chronological relationship between calibrated ages for each archeological site considered in this study and inferred paleoclimate conditions along the western Andean slope in the interval 7-18 ka BP. Light blue bars represent Central Andean Pluvial Event (CAPE) phases, while orange bars denote negative hydroclimate conditions. Vertical dashed line delineates the Pleistocen-Holocene transition. Archeological dates were calibrated in Calib 7.0.4 by using the SHCAL 13 calibration curve.

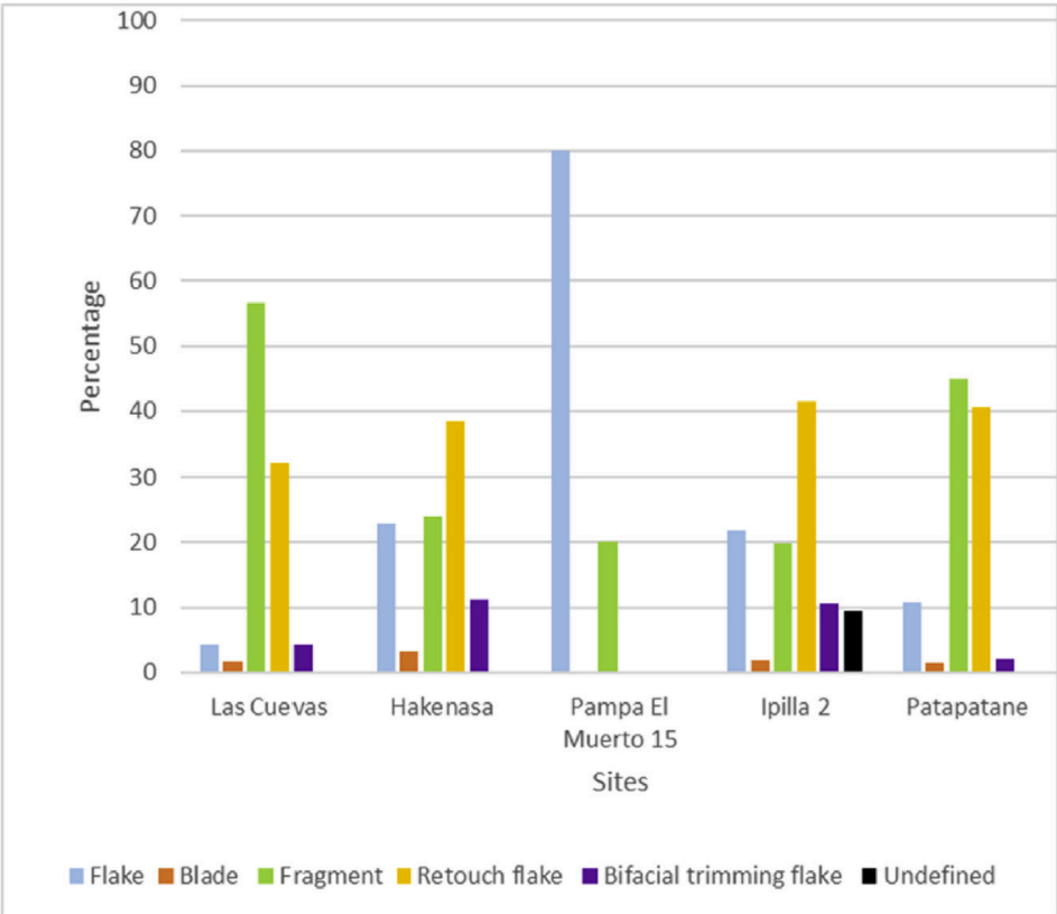

Fig. 3. Percentage of debitage products identified at the different Dry Puna sites of northern Chile.

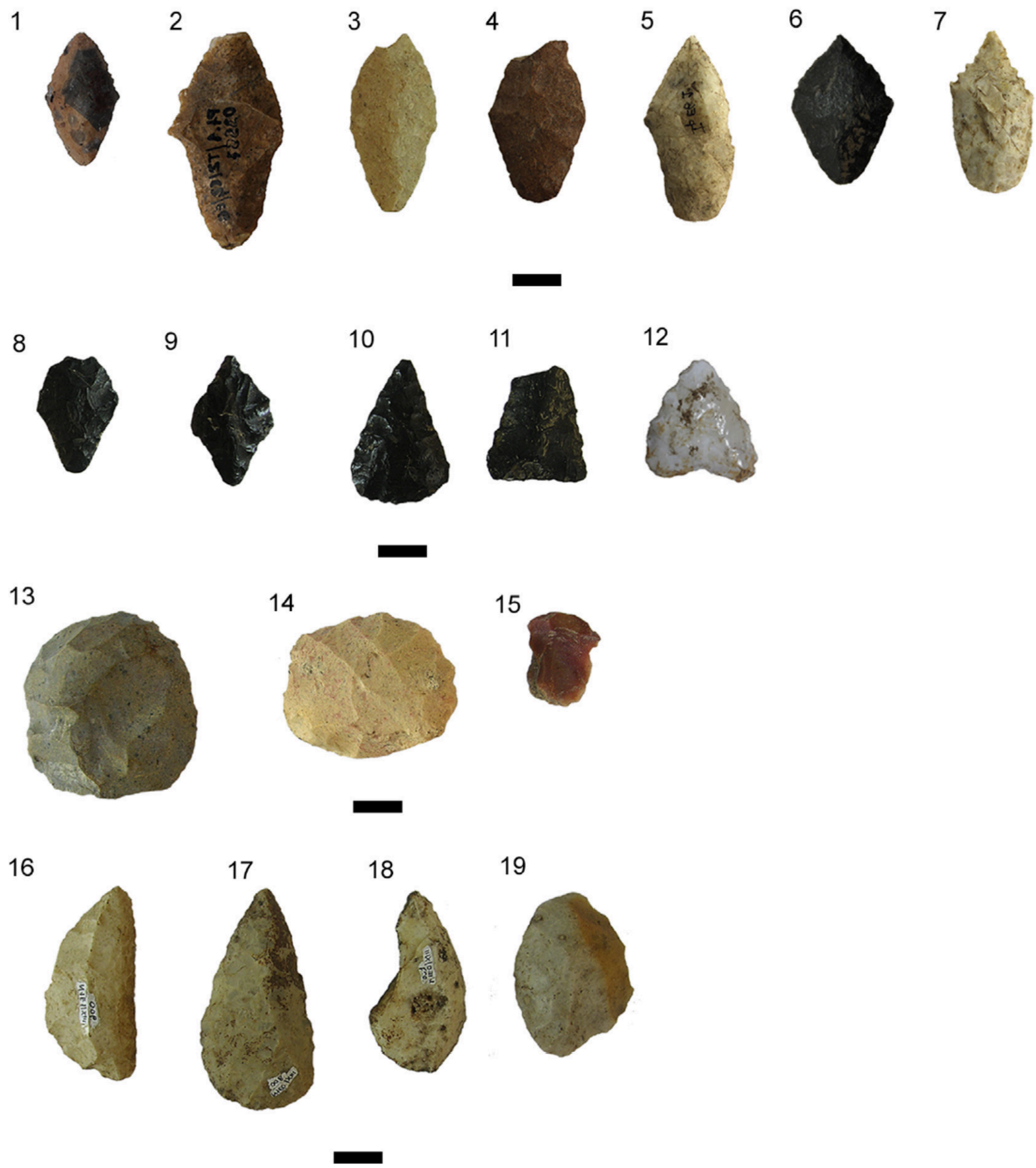

Fig. 4. Lithic tools from the studied sites. Stemmed projectile points with shoulders "Patapatane type": (1, 2, 6), Patapatane, (3) Hakenasa (4, 5, 7) Ipilla. Tetragonal projectile points: (8, 9) Hakenasa. Unstemmed triangular projectile points with convex base (10 Hakenasa), straight base (11 Hakenasa), and concave base (12 Patapatane). Hakenasa scrapers (13, 14, 15), Hakenasa sidescrapers (16, 17, 18, 19).

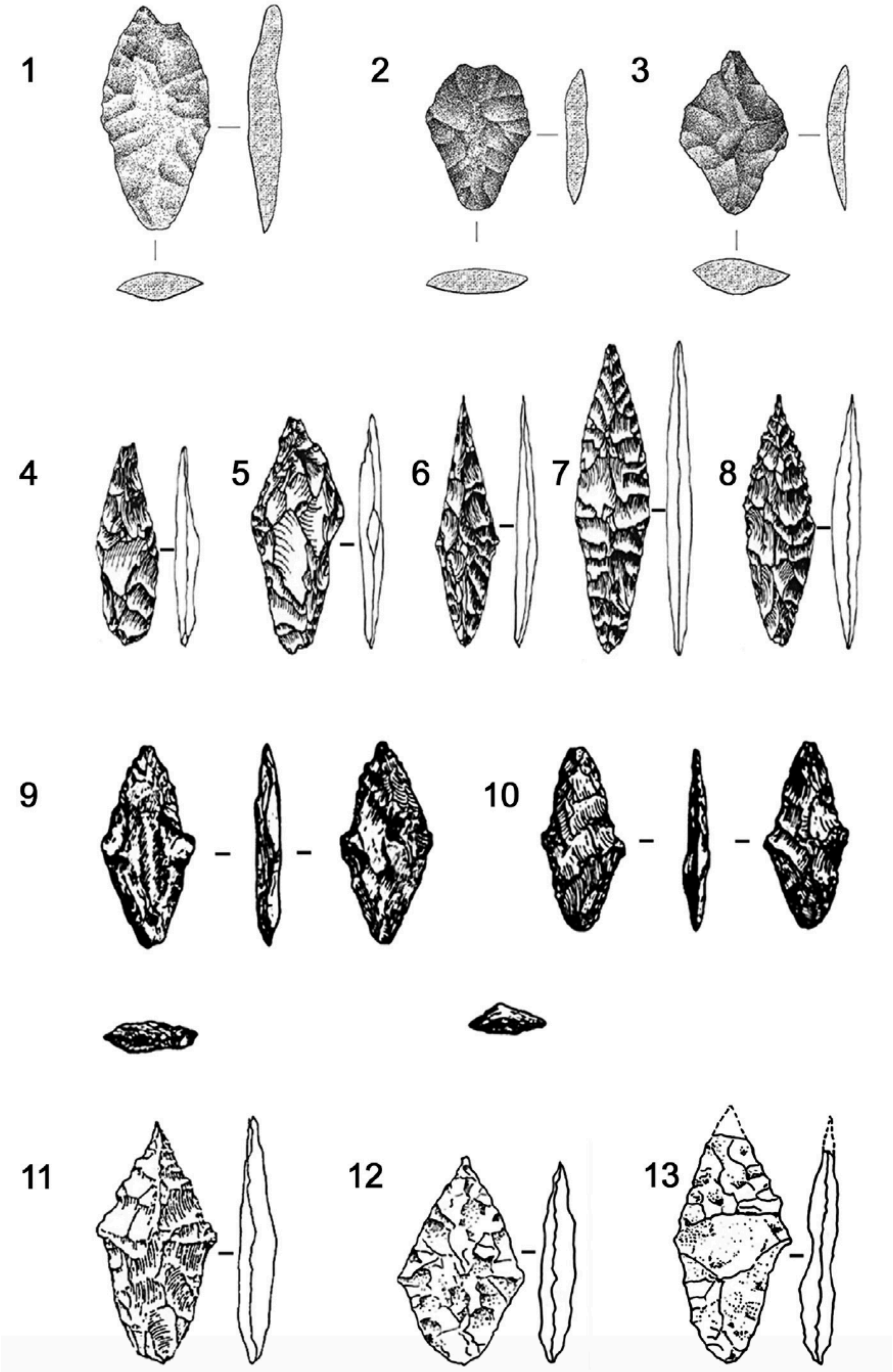

Fig. 5. Similar projectile points types from different sites of the Andean highlands. (1-3) Hakenasa (after Osorio et al., 2011: Fig. 7); (4-8) Asana (after Aldenderfer, 1998: Fig. 6.24); (9-10) Caru (after Ravines, 1967: Fig. 26); (11) Telarmachay (after Lavallee, 1994: Fig. 5); (12-13) Patapatane (after Santoro and Nunez, 1987: Fig. 5).

Table 1. 41 AMS radiocarbon dates for archeological sites discussed in the text. All radiocarbon dates were calibrated using CALIB 7.0.4 at 2-sigma with the Southern Hemisphere correction.

Site	Level	Lab-Code	^{14}C yr BP	Age (cal yrs BP)	Lower cal range BP	Upper cal range BP	Material dated	Reference
Hakenasa	Level 13	Beta-187535	9580 ± 40	10,890	10,700	11,090	Charcoal	LeFebvre 2004
Hakenasa	Level 14	UCIAMS-145003	9655 ± 40	10,940	10,770	11,160	Camelid tooth	Osorio et al. in press
Hakenasa	Level 13	UCIAMS-77761	9830 ± 40	11,210	11,150	11,260	Charcoal	Osorio et al., 2011
Hakenasa	Level 13	UCIAMS-77762	9975 ± 40	11,330	11,240	11,600	Charcoal	Osorio et al., 2011
Hakenasa	Level 13	UGAMS-2953	9980 ± 40	11,340	11,240	11,600	Charcoal	Osorio et al., 2011
Hakenasa	Level 12	Beta-187534	9520 ± 70	10,760	10,560	11,090	Charcoal	LeFebvre 2004
Hakenasa	Level 11	Beta-187533	9260 ± 60	10,380	10,240	10,550	Charcoal	LeFebvre 2004
Hakenasa	Level 11	Beta-187532	9170 ± 70	10,310	10,190	10,500	Charcoal	LeFebvre 2004
Hakenasa	Level 10	Beta-187531	8789 ± 60	9740	9540	10,120	Charcoal	LeFebvre 2004
Hakenasa	Level 23	I-13287	8340 ± 300	9230	8460	10,120	Charcoal	Santoro and Núnez 1987
Ipilla 2	15	UGAMS-4588	8510 ± 30	9490	9440	9530	Charcoal	Santoro et al., 2011
Ipilla 2	N1-1 8	UCIAMS-77765	8600 ± 40	9530	9470	9600	Charcoal	Santoro et al., 2011
Ipilla 2	N1-1 7	UCIAMS-77764	8635 ± 40	9550	9490	9660	Charcoal	Santoro et al., 2011
Ipilla 2	N1-1 6	UCIAMS-84348	8675 ± 25	9580	9530	9670	Charcoal	Santoro et al., 2011
Ipilla 2	N1-0 10	UCIAMS-77767	8690 ± 40	9600	9530	9700	Charcoal	Santoro et al., 2011
Ipilla 2	N1-1 9	UCIAMS-77766	8695 ± 40	9600	9530	9730	Charcoal	Santoro et al., 2011
Ipilla 2	N1-0 13	UCIAMS-77770	8695 ± 40	9600	9530	9730	Charcoal	Santoro et al., 2011
Ipilla 2	Ipilla 2/S4-0/1	UCIAMS-165635	8700 ± 70	9640	9520	9890	Charcoal	This study
Ipilla 2	S5-0/2B	UCIAMS-165632	8725 ± 25	9620	9540	9700	Charcoal	This study
Ipilla 2	N1-0 11	UCIAMS-77768	8730 ± 35	9630	9540	9760	Charcoal	Santoro et al., 2011
Ipilla 2	S4-0/2A	UCIAMS-165633	8780 ± 25	9700	9560	9890	Charcoal	This study
Ipilla 2	Exposed profile	CAMS-124594	8785 ± 30	9710	9560	9890	Charcoal	Santoro et al., 2011
Ipilla 2	S4W1/2B-C	UCIAMS-165636	8820 ± 25	9780	9630	10,110	Charcoal	This study
Ipilla 2	S5-0/2B-C	UCIAMS-165638	8820 ± 25	9780	9630	10,110	Charcoal	This study
Ipilla 2	N1-0 12	UCIAMS-77769	8825 ± 40	9800	9560	10,120	Charcoal	Santoro et al., 2011
Ipilla 2	Exposed profile	CAMS-124595	8840 ± 30	9820	9660	10,130	Charcoal	Santoro et al., 2011
Ipilla 2	S4-0/2-	UCIAMS-165639	8845 ± 25	9830	9680	10,120	Charcoal	This study
Ipilla 2	Exposed profile	CAMS-124596	8845 ± 30	9830	9680	10,130	Charcoal	Santoro et al., 2011
Ipilla 2	S4W1/2C	UCIAMS-165634	8890 ± 25	9960	9750	10,160	Charcoal	This study
Ipilla 2	S4W1/2-	UCIAMS-165637	8940 ± 30	10,030	9900	10,180	Charcoal	This study
Las Cuevas 2	T2-IVC	Beta-298938	10,040 ± 70	11,490	11,250	11,760	Charcoal	Santoro et al., 2011
Las Cuevas 2	E8/IVC	UCIAMS-165646	10,070 ± 30	11,520	11,330	11,720	Charcoal	Osorio et al. in press
Las Cuevas 2	Level 11	I-13128	8270 ± 250	9160	8460	9700	Charcoal	Santoro and Chacama 1984
Las Cuevas 2	Level 13	I-12835	9540 ± 160	10,810	10,300	11,210	Charcoal	Santoro and Chacama 1984
Las Cuevas 2	T2-IVA	Beta-298937	9630 ± 70	10,940	10,710	11,170	Charcoal	Osorio et al. in press
Pampa El Muerto 15	Level 9	Beta-335686	8190 ± 40	9090	9000	9250	Burned bone	Osorio et al., 2016
Pampa El Muerto 15	Level 13	Beta-319884	9510 ± 50	10,720	10,570	11,070	Burned bone	Osorio et al., 2016
Patapatane	Level G	Beta-238853	7010 ± 40	7800	7690	7930	Charcoal	Santoro et al., 2011
Patapatane	Level 20	Beta-43019	7970 ± 110	8780	8460	9070	Charcoal	Santoro et al., 2005
Patapatane	Level J	I-12837	8160 ± 340	9030	8210	9890	Charcoal	Santoro and Chacama 1984
Patapatane	Level J	Beta-238852	8440 ± 80	9400	9140	9540	Charcoal	Santoro et al., 2011

Table 2. Site description and frequencies of the studied materials.

Site	Elevation (masl)	Camp category	Studied occupation level	Excavated area (m^2)	Lithics	Animal bones
Las Cuevas	4485	Rock shelter	IVc	3	357	6
Hakenasa	4100	Cave	13-14	6	1284	2849
Pampa El Muerto 15	3174	Rock shelter	13	1.5	26	140
Ipilla 2	3400	Open-air site	6-12	1.5	1888	288
Patapatane	3800	Cave	J	7	912	586

Table 3. Provenience of the main raw materials categories identified in the studied sites.

Sites	Siliceous	Obsidian	Basalt
Las Cuevas	Extra-Local	Probably Local	Extra-local
Hakenasa	Extra-Local	Probably Local	Extra-local
Pampa El Muerto 15	Probably Local	Extra-local	Extra- local

Table 4. Percent of cortex present in the dorsal surface of the debitage products by site.

Cortex Percent	Las Cuevas	Hakenasa	Pampa El Muerto 15	Ipilla	Patapatane
No cortex	94.92	81.54	100	98.5	98.5
Less <50	4.52	15.75		1.02	1
More >50	0.56	2.73		0.27	0.2
Full cortex				0.21	0.2