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Hunter-gatherer mobility decisions and synchronous climate change in the Southern Andes: The early and middle Holocene occupations of ARQ-18, San Juan, Argentina (29.5°S)

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A B S T R A C T

In the southern Andes, Holocene climate records show drastic changes in moisture during the early and middle Holocene. To generate a more refined chronology of climate changes in this region, we present a Bayesian model that combines published cosmogenic dates from the Encierro Valley (29.1°S) and radiocarbon dates on peat and soils from the western slope of the Andes (27–33°S). We compare this to a similar model from the high-altitude archaeological site ARQ-18 in the Las Taguas Valley (29.5°S), San Juan, Argentina. These chronologies indicate synchronous changes in climate and occupational intensity, which shed light on hunter-gatherer mobility decisions. This site was first occupied in the early Holocene, when nearby valleys were deglaciated by around 10,700 cal BP. ARQ-18 was occupied a few centuries later around 10,100 cal BP. The site was first colonized during a regional wet phase, probably by hunters from the highlands to north who moved quickly among humid high-altitude valleys. As regional moisture began dropping around 8700–7800 cal BP, occupational intensity at ARQ-18 reached a maximum as diverse groups gathered in the valley. At this point, an important environmental threshold was crossed as groups reversed their mobility patterns and decisions and did not occupy the site for 1700 years. This "archaeological silence" correlates closely with the middle Holocene's hyperaridity during 7800–5700 cal BP. As soon as humidity returned, groups began visiting the site again. From this point on, strategies increasingly incorporated herding in response to less stable environmental conditions.

1. Introduction and regional setting

Mobility is one of humans' most successful cultural and biological adaptions. Moving in response to seasonal or regional climate shifts and resource availability has been foundational to *Homo sapiens*' long-term fitness (Kelly, 1995; Bettinger et al., 2015). It is even more critical in environments such as deserts (Veth et al., 2005) and cold mountainous regions (Aldenderfer, 1999) because resources are widely-spaced and unpredictable in space and time. Past inhabitants of these environments and their mobility decisions can be better understood by integrating environmental and archaeological data.

Recent climate research on the Holocene in South America has reported increasingly clear and temporally coincident proxies, for example of the middle Holocene's period of extreme aridity (Gil et al., 2005; Grosjean et al., 2007; Tchilinguirian and Morales, 2013). This research has begun to identify shifts at smaller spatial scales and approach century-scale resolution. In many cases, there are archaeological and environmental records from the same or adjacent regions, which has increased the spatial resolution and hence the possibility of examining differences between neighboring regions instead of using large-scale generalizations. These finer temporal and spatial scales bring us closer to the human scale of the people who lived through these changes and made mobility decisions.

The arid mid-Holocene corresponds to a well-known temporal gap in the archaeological record in many parts of the central and southern Andes, known as an "archaeological silence" (Aldenderfer and Flores Blanco, 2011; Núñez et al., 2013). The lack of archaeological data has made it difficult to differentiate between a series of alternative explanations for this silence: taphonomic factors reduced the material signal of extant populations (García, 2005), active volcanoes drove changes (Durán and Mikkan, 2009), there were fewer people living in the region due to a population

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bottleneck (Barberena, 2015), groups modified their mobility patterns to exploit more distant resources (Garvey, 2008; Méndez et al., 2015) or specific ecorefugia (Ledru et al., 2013; Núñez et al., 2013), or they abandoned large areas (Neme and Gil, 2009). All of these factors probably played a role at the regional scale and are useful starting points for exploring specific cases.

This paper presents a case study from the archaeological site ARQ-18, which shows a series of temporal correlations between environmental and climate changes that reveal factors in past mobility decisions in the early and middle Holocene Andes. ARQ-18 is rock shelter in the Las Taguas Valley in the province of San Juan, Argentina that was occupied throughout the Holocene (Figs. 1 and 2). The valley is located near the continental divide at 3760 masl. The environment includes extensive *vegas* (Teillier, 2005), lush, high-altitude meadows that have attracted guanacos, hunters, llamas, and herders for thousands of years (Figs. 3 and 4). This high, moist valley is a preferred location for summer stays but is resource-poor during the winter when most of it is covered in snow. Currently, modern goat herders from the western lowlands bring their herds to pasture for five months during the summer (Gambier, 1986; Gasco et al., in press). Past herders may have followed a similar annual round, though it is also possible that groups came and went from eastern valleys via a longer, more difficult route (Castro et al., 2013; Lucero et al., 2014a,b).

Data from this site are important for exploring regional patterns because very little archaeological information is available for this area, with the exception of Inca-period sites (Schobinger, 1966; Stehberg, 1995). It is one of the only early–middle Holocene sites in the wide latitudinal band 26.2–30.7°S of the Andes (see García, 2003; Jackson et al., 2004; Rivero and Berberián, 2008; Pintar, 2008b). It is the earliest dated site in the Province of San Juan, which is notable considering Gambier's (1974, 1977) decades of large-scale excavations in rock shelters in central and southern San Juan (30–31°S). Given the few extant data, the data presented here serve as a baseline for regional patterns, which should be tested against future environmental and archaeological data. The archaeological record of ARQ-18 reflects the ways that its occupants adjusted their mobility circuits and subsistence in response to changes in the climate and more specifically, the increasing aridity of the middle Holocene Andes. In this way this research contributes to the regional and even global discussion of synchronous cultural and climatic changes during this period (e.g. Anderson et al., 2007;

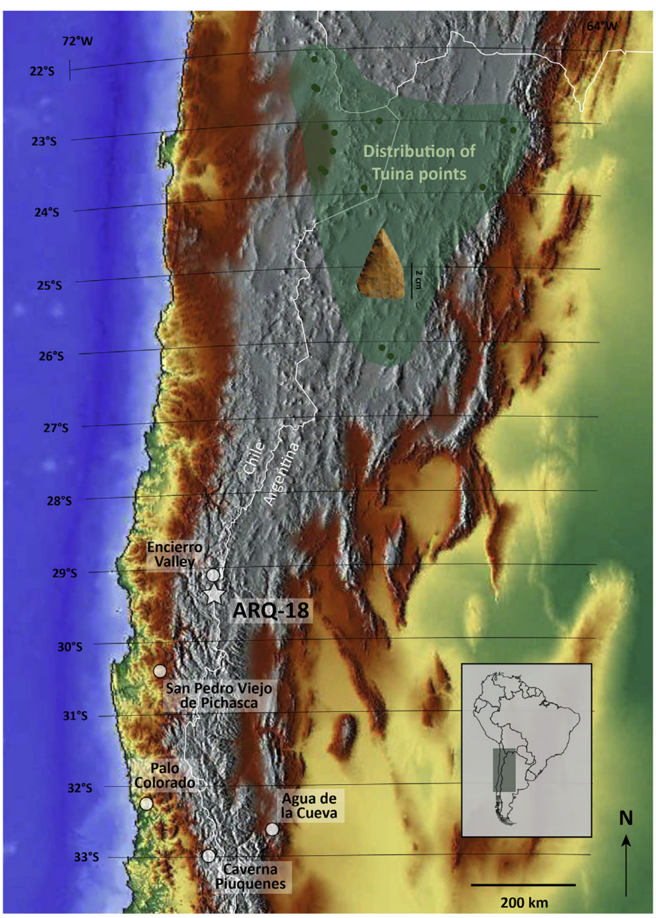


Fig. 1. Map of the southern Andes showing archaeological and climate archive sites mentioned in the text. Tuina point distribution indicated in green. The pictured point is from component 5 of ARQ-18 (Table 4). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

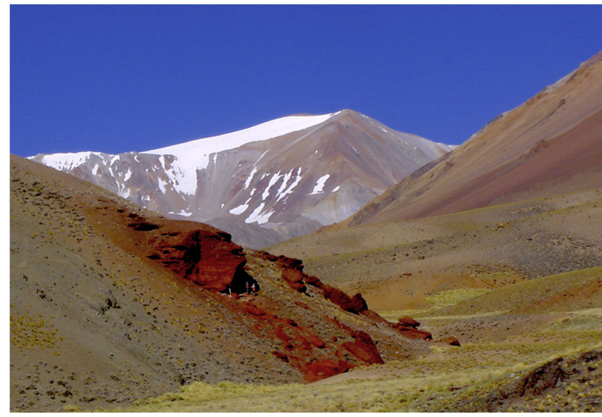


Fig. 2. The large ARQ-18 rock shelter during excavation.

Fig. 3. View of a high-altitude meadow (or *vega*) in the Las Taguas Valley, highlighting the contrast between the rocky slopes and lush valley bottom.

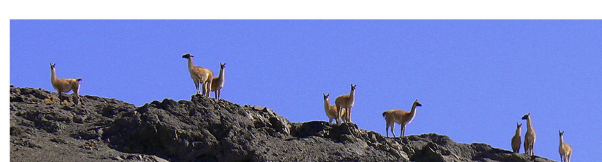


Fig. 4. A troop of guanacos overlooking the excavation.

Neme and Gil, 2009; Mondini et al., 2013; Núñez et al., 2013; Ratto et al., 2013; Yacobaccio, 2013).

The paper begins with an overview of the climate history in the region and compares it to a more local climate history with a Bayesian model that combines cosmogenic dates from the nearby Encierro Valley (Zech et al., 2006) and radiocarbon dates from peat and soils from the western slope of the Andes (Veit, 1996). The next section discusses the human occupation of the region based on archaeological data from ARQ-18, using a similar Bayesian model. These refined chronologies are the basis for the discussion section, which highlights synchronous changes in climate and cultural histories. Here we address the paper's main goal, integrating the two lines of evidence to clarify how climate affected mobility decisions in the high-altitude Andes.

2. Materials and methods: radiometric dates and Bayesian models

The advantages of Bayesian chronologies for archaeologists have become clear over the last few decades (see Buck et al., 1991; Buck and Millard, 2004; Litton and Buck, 2007; Bayliss, 2009; Bronk Ramsey, 2015). First, that they make it possible to incorporate independent chronological information into radiocarbon chronologies, such as stratigraphic relationships. This independent information constrains dates' probability distributions. Second, models can interpolate probability distributions for events that cannot be directly dated. For example, to estimate when a site was founded, it is very difficult to identify a representative carbon sample from a site's very first occupation, or a carbon sample that accurately dates the interphase between two occupational strata. However, Bayesian models can be queried for the timing of these events and estimated with error ranges, which can be continually improved with additional dates (e.g. Bronk Ramsey, 2009; Whittle et al., 2011; Marsh, 2012, 2015). They can incorporate different types of historic or radiometric dates as well as other temporal information. Estimating dates in this way is statistically much more robust than the common practice of relying on a single date, often uncalibrated, that is near the depositional event. Events estimated in this way are key to effective comparisons between different types of chronologies, which is the main purpose of this paper.

This paper uses three sets of published radiometric dates to build two Bayesian models, one with environmental data and one with archaeological data. The models were run in OxCal 4.2 (Bronk Ramsey, 2009) with the SHCal13 calibration curve for radiocarbon dates (Hogg et al., 2013). In the text and tables, we report dates' medians rounded by 100 years and 1-sigma errors rounded by 10 years. This simplification improves readability but we stress that in interpreting chronological correlations, it must not be forgotten that calibrated error ranges are not symmetrical and that the actual date may be away from the median, especially for dates with large error ranges or multiple intercepts with the calibration curve. The complete results and error ranges can be found in Appendices A and B, rounded by 10 years.

The timing of environmental changes in the region around ARQ-18 are estimated with 27 radiometric dates from the western slope of the Andes (27–33°S). Cosmogenic dates are used to model the timing of early Holocene deglaciation (Zech et al., 2006). Following the authors' interpretation, we use the seven most reliable dates. Next we added 20 radiocarbon dates from peat and soils that indicate the timing of wet and dry periods (Veit, 1996). The Bayesian model integrates both data sets and provides quantified estimates of the timing of shifts between climate regimes, which cannot be directly dated. These dates were built into a single Bayesian model with a sequence of five phases: the glacial maximum, deglaciation, the wet early Holocene, the wet late mid-Holocene, and the variable late Holocene. The second and third phases were treated as overlapping to allow for the possibility that the moist early Holocene began as glaciers were still retreating. To estimate when changes occurred, we used boundaries between contiguous phases and first and last dates for the two overlapping phases. For the one phase without dates, the arid early middle Holocene, we used the first and last dates of the surrounding phases.

The timing of cultural changes is based on 18 radiocarbon dates from ARQ-18, which so far have not been calibrated (Cortegoso et al., 2012a, Table 2; Castro et al., 2013, Table 1; Cortegoso, 2014). Even though uncalibrated chronologies continue to be used in hunter-gatherer archaeology in the Andes, calibrated and modeled chronologies are necessary for more refined sequences and comparisons to climate data. The radiocarbon dates were modeled as four contiguous phases, one each for occupational components 3–5 and a single phase for components 1–2. The components were defined based on the site's stratigraphic and material patterns (see Cortegoso, 2014). The model was built and was queried in the same way as the environmental model.

We compared phase boundaries and first and last dates from both the environmental and archaeological models. Correlations within a few centuries were considered simultaneous at this study's scale of analysis, as 1-sigma ranges are 1–2 centuries for most modeled events. We interpret both models at the same temporal scale, in an attempt to reduce problems that can arise from using environmental and cultural chronologies of disparate scales (Callaway, 2005). The most significant correlations between these chronologies can reveal emergent episodes of rapid, significant change (Marsh, in this issue). In making comparisons, correlated inflection points and transitions are much more revealing than correlated phases. Hence correlated transitions are the focus of this study, which can be modeled with Bayesian statistics, making this a robust methodology for exploring potential correlations. Improved Bayesians models and additional dates will increase the chronological resolution of the models presented here, possibly showing even stronger correlations.

3. Climate reconstruction: late Pleistocene to middle Holocene

Climate reconstructions for the 29–31°S latitudinal band are based a number of proxies, including high-resolution records that identify large-scale trends. This summary focuses on 1) results from environmental Bayesian model (Table 1) and 2) pollen data from the Chilean coast (31–32°S) that reveal a high-resolution humidity chronology (Villagrán and Varela, 1990; Maldonado and Villagrán, 2002, 2006; Maldonado et al., 2010; Méndez et al., 2015, Fig. 2). The former is based on data that are closer to the archaeological site while the latter has better temporal resolution. The environmental model presented here is also based on high-altitude data, which agrees with lower-altitude proxies such as pollen. The few high-altitude climate studies that have been done show the same general climate trends as coastal data (de Jong et al., 2013), so they are appropriate for reconstructing regional trends. Combined with other climate research, these data sets describe the nature and timing of successive climate regimens from the late Pleistocene through the middle Holocene.

During the late Pleistocene, many high-altitude Andean valleys were dominated by glaciers (Ammann et al., 2001; Kull et al., 2002). The Bayesian model's cosmogenic dates from the Encierro Valley (Zech et al., 2006) indicates that the glacial maximum lasted from

Table 1
Modelled dates for climate changes from a Bayesian model of cosmogenic dates of boulders in the Encierro Valley (Zech et al., 2006) and radiocarbon dates of soil samples from multiple sites on the western slope of the Andes (Veit, 1996).

Phase	Median starting and ending dates (cal BP)		Modelled events
		±	
Variable late Holocene	3300–2900	100–210	Boundary–Last
Wet middle Holocene	5700–3300	110–210	First–Boundary
Dry middle Holocene	8100–5700	80–110	First–Last (surrounding phases)
Wet early Holocene	10,900–8100	80–150	First–Last
Deglaciation	12,700–10,700	320–650	Boundary–Last
Glacial maximum	13,800–12,700	450–650	First–Boundary

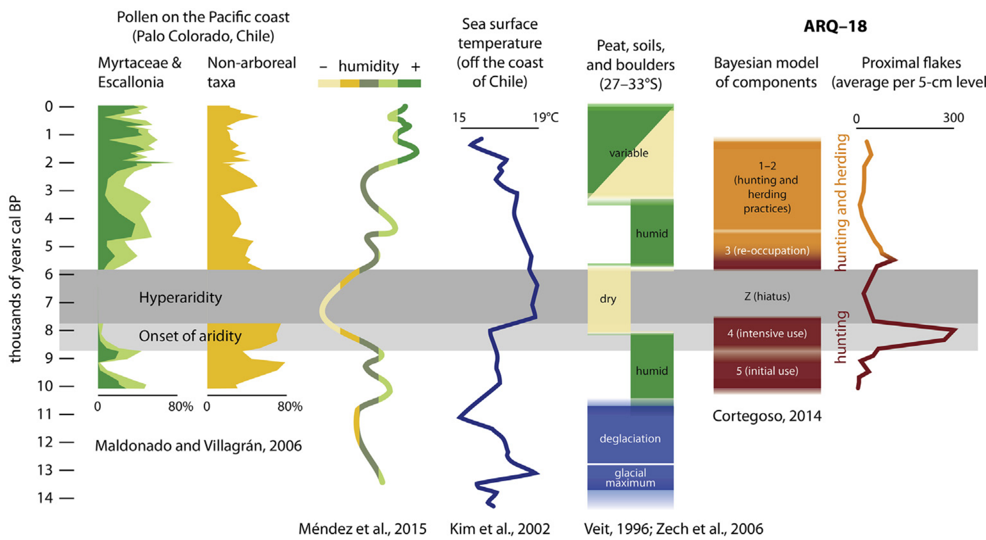


Fig. 5. Comparisons of climate and archaeological chronologies.

around 13,800 to 12,700 cal BP (Appendix A, Fig. 5, Table 1). The following deglaciation phase lasted until 10,7000 cal BP. Pollen data suggest that deglaciation took place during a dry period that ended around 10,800 cal BP (Méndez et al., 2015, Fig. 2), marking the beginning of the moist early Holocene. The environmental model agrees, estimating this transition at 10,900 cal BP (Table 1), when organic soils began to form on the western slope of the Andes at multiple sites from 27 to 33°S (Veit, 1996).

The early Holocene began with rapid increases in sea surface temperature and humidity (Kim et al., 2002; Maldonado and Villagrán, 2006, pp. 251–252), which both reached significant peaks by 10,000 cal BP, correlated with the growth of *Nothofagus* forests in southern Patagonia (McCulloch et al., 2000, Fig. 3c; Kilian and Lamy, 2012, Fig. 7). High humidity, probably from coastal fogs, is suggested by stable soil evolution on the western slope of the Andes (Veit, 1996, pp. 114). ENSO activity was also very reduced, contributing to inter-annual climate stability (Sandweiss, 2003; Vargas et al., 2006). These regional conditions would have been conducive to the formation of productive ecosystems in high altitude Andean valleys.

The early mid-Holocene was marked by a drastic reduction in moisture. Regional climate signals suggest this period began around 8500 cal BP (Kilian and Lamy, 2012, pp. 13), which is similar to the environmental model's date, 8100 cal BP (Table 1). Higher-resolution data are available from trends in pollen, which show that humidity decreased from 8700 to 7800 cal BP (Maldonado and Villagrán, 2006, pp. 252). A period of intense aridity in the region followed as the Westerlies shifted south toward Patagonia (Veit, 1996; Lamy et al., 2001; Jenny et al., 2002, 2003; Gilli et al., 2005; Mayr et al., 2007). There was a synchronous spike in sea surface temperature off the Pacific coast (Kim et al., 2002). ENSO activity was reduced or even absent during this period (Sandweiss, 2003; Rein et al., 2005). This extended dry period ended around 5700 cal BP, a date from pollen and other proxies (Jenny et al., 2002; Maldonado and Villagrán, 2006; Méndez et al., 2015). On the western slope of the Andes, there was a lack of organic soils from 8100 to 5700 cal BP (Table 1). This period of aridity was drastic, enduring, and widespread, and has been well-documented by large-scale climate studies (Grosjean et al., 2007; Wanner et al., 2008). The end of this period saw a return to wetter but more variable conditions in the late Holocene, beginning around 3300 cal BP, according to the environmental model. At the same time, ENSO variability was high, according to a multi-proxy review (Donders et al., 2008).

In summary, these millennia saw major climate changes. A series of proxies from the Pacific coast show similar regional trends, which correlate with soil formation on the western slope of the Andes and the environmental Bayesian model. These regional patterns most likely apply to the higher Andean valleys as well. Shifts in both coastal and mountain environments had significant impacts on human mobility decisions, which can be tracked through archaeological data.

4. The late Pleistocene–early Holocene human occupation of the high-altitude Andes

South America was first colonized during the late Pleistocene by coastal-adapted groups that moved rapidly southward along the 'kelp highway' (Erlandson et al., 2007; Jackson et al., 2007). They colonized the southern Pacific coast and inland Patagonia prior to

13,000 cal BP (Miotti and Salemme, 2003; Jackson et al., 2007; Dillehay et al., 2008; Jackson et al., 2012; Méndez, 2013). High-altitude areas of the Chilean and Argentine Andes were first occupied after 13,000 cal BP. The earliest occupations, north of 25°S, date between 12,000 and 13,000 cal BP (Fig. 5), while the majority of these early sites were first occupied after 11,500 cal BP as part of a regional demographic increase (Jackson et al., 2004; Grosjean et al., 2005; Rivero and Berberián, 2008; Osorio et al., 2011; Yacobaccio and Morales, 2011; Latorre et al., 2013; Rademaker et al., 2014). At this point, glaciers were receding as low temperatures and a significant dry period were coming to an end, making resource-rich, high-altitude valleys more accessible. South of 26°S, there are scant archeological data for this period. ARQ-18 is located at 29.5°S; it is detailed below. South of ARQ-18 (30–31°S), the dearth of early Holocene sites is notable as Gambier (1974, 1977) spent decades excavating high-altitude rock shelters in this area (Rivero and Berberián, 2008). At 32°S, there are two sites on both sides of a major Andean pass, Caverna Piuquenes at 2100 masl (Stehberg et al., 2012) and Agua de la Cueva at 2900 masl (García et al., 1999). The starting boundaries of single-phase Bayesian models of dates from these sites suggest initial occupations at 11,900 and 13,300 cal BP, respectively. The early date from Agua de la Cueva indicates that it was occupied during a local glacial advance, suggesting that coastal groups were exploring the highlands from a very early date and access was not blocked by glaciers, similar to highland Peru (Rademaker et al., 2014). From 32°S to 36°S, there is another large area with few data. Further south, the Andes drop in elevation and the environment changes dramatically. The very sporadic presence of archaeological data over such a large area seems to reflect a combination of 1) a lack of systematic surveys, 2) poor preservation of early sites, and 3) low population densities and high mobility. All of these factors apply to the region around ARQ-18.

5. Excavations at ARQ-18: chronology and shifting occupational intensity

ARQ-18 is a high-altitude rock shelter site in a glacial valley that drains into the Las Taguas River, along which 29 sites have been identified. Recent dissertations have focused on the organization of lithic technology (Castro, 2015; Lucero, 2015) and identifying wild and domestic camelid bones (Gasco, 2013). Detailed treatments of these issues as well as the valley's geomorphology and the spatial organization of archaeological data have been presented in a series of recent journal articles and book chapters (Cortegoso et al., 2012a, 2012b; Castro et al., 2013, 2014; Cortegoso, 2014; Gasco, 2014; Llano and Fernández, 2014; Lucero et al., 2014a,b; Winocur, 2014).

The abundant material record of ARQ-18 (16,224 lithic artifacts) covers most of the Holocene and is dominated by discarded flakes from lithic tool production (Cortegoso, 2014), in addition to many large mammal and camelid bones (Gasco, 2014). It is close to many *vegas*, where large mammals such as vicuñas and guanacos would have grazed during the summer (Figs. 3–5). These animals were valued prey, which were hunted with spears and darts beginning in the early Holocene. There is a prominent occupational hiatus in the middle Holocene. By the Late Holocene, people hunted wild animals and herded domestic llamas (Gasco, 2013, pp. 359–364). This section summarizes the stratigraphy and relevant material patterns for the five occupational components (see detail in Cortegoso, 2014; Gasco, 2014; Castro, 2015).

ARQ-18 comprises a group of stone structures near a large rock shelter with an eave and walls that define an entryway (Castro et al., 2013, pp. 96). It was excavated in 5-cm artificial levels and the sloping bedrock was reached 2.75–3.15 m below the surface (Cortegoso, 2014). Like at many rock shelters, the stratigraphy was complex and layers were not horizontally level. Sediment accumulating over the bedrock was sloped, gradually became more level, and then the rock shelter's overhang collapsed and sloped deposition resumed. Occupants dug pits for fires and building structures, further disturbing the stratigraphy. To account for this, levels were grouped into five occupational components that are clearly distinguished in stratigraphy and artifact patterns, an approach that reduces the impact of possible stratigraphic mixing between individual levels.

Occupational intensity varied over time, from a combination of any of the following: shorter or longer stays depending on the length of the summer, smaller or larger groups, or activities that were more or less focused on lithic tool production and maintenance. Occupational intensity can be tracked with proximal flake counts, which approximate the minimum number of blows during lithic tool making (Andrefsky, 1998; Hiscock, 2002). These counts exclude very small flakes that easily migrate to lower layers. The trend of proximal flake counts was smoothed by averaging 2–3 excavation levels within the same component into 5-cm averages (Table 2). Raw lithic artifact counts show a similar overall trend (Cortegoso, 2014: Fig. 21). We also estimated the number of proximal flakes per century, based on the durations of each component, which were estimated with the Bayesian model (Table 3).

Table 2
Results of the Bayesian model and proximal flake counts from ARQ-18.

Component	Duration (calendar years)		Proximal flakes	
	Median	±	n	n per century
1–2	3400	580	355	10
3	1400	280	670	48
Z (hiatus)	1700	100	29	2
4	1200	320	1337	111
5	1400	550	246	18

Table 3
Results of the Bayesian model of ARQ-18.

Component	Modelled date (cal BP)		Modelled events
	Median	±	
1–2	4500–1200	80–500	Boundary–End Boundary
3	5900–4500	80–270	First–Boundary
Z (hiatus)	7600–5900	70–80	First–Last (surrounding phases)
4	8700–7600	70–310	Boundary–Last
5	10,100–8700	310–390	Start Boundary–Boundary

5.1. Early Holocene: component 5

Component 5 is the earliest component, roughly 80 cm deep, and lies directly over bedrock. The Bayesian model estimates that occupation began around 10,100 cal BP (Appendix B, Table 3). The matrix is dominated by eroded and fallen portions of the rock overhang (Cortegoso, 2014, pp. 32). The high density of degraded material created a deep component that accumulated relatively quickly, so artifact densities underestimate occupational intensity. There are organic lenses and hearths but with almost no faunal or botanic remains due to poor preservation (Gasco, 2014, pp. 179–182; Llano and Fernández, 2014). The material signature is almost entirely chipped stone, including projectile points and lithic debitage. Some of the individual levels within this component have very few or even no artifacts, and not all the local lithic sources were used, suggesting low-intensity or discontinuous occupation (Cortegoso et al., 2012b; Cortegoso, 2014, pp. 39; Castro, 2015). The discard rate is 18 proximal flakes per century for this 1400-year component (Table 2). The average number of proximal flakes in the earliest levels is under five but reaches 44 in the latest levels, a nine-fold increase (Fig. 5). Correspondingly, the number of regional lithic sources used increases from two to five, which is close to the site's maximum of six sources (Castro, 2015). This trend intensifies in component 4.

5.2. Early Holocene: component 4

The later part of the early Holocene marks a period of very intense use of the rock shelter. This component began around 8700 cal BP, the temporal boundary between components 4 and 5 (Table 3). This 40-cm thick component has a markedly different matrix of fine-grained reddish loam (Cortegoso, 2014, pp. 29–32). It includes a series of ash pits, hearths, successive organic-rich strata, and the site's highest density of lithic artifacts, 111 proximal flakes per century (Table 2). All types of lithic debitage and all local lithic sources are represented, in addition to an arrow shaft fragment. Unlike the previous component, occupation was continuous and intense, suggesting more frequent use, longer periods of use, and probably larger groups (Castro et al., 2013; Cortegoso, 2014; Castro, 2015). Lithic data suggest intense occupation by highly mobile groups making projectile points and taking them as they left the site. Few instruments and points were left at the site, but there was a high quantity of bifacial thinning flakes as well as pressure flakes from forming and maintaining tool edges.

5.3. Middle Holocene hiatus: component Z

The stratigraphic interphase between components 4 and Z marks the beginning of a 1700-year occupational hiatus, the temporal difference between the initial and final dates of components 3 and 4, 7600–5900 cal BP (Table 3). The onset of the hiatus is stratigraphically defined by a compact, gray loam that extends throughout the excavation. Above this there is a 15- to 20-cm layer with very little archaeological material (Cortegoso, 2014, pp. 225–226). The homogenous dark red loam matrix is unlike that of adjacent levels and probably accumulated through the actions of wind and water (Winocur, 2014). There are no hearths and material density is extremely low, just two proximal flakes per century (Table 2). The number of flakes per 5-cm level drops to 15, a 20-fold decrease from the previous component (Fig. 5). Although this is clearly an occupational hiatus relative to other components, the material record is never completely absent.

5.4. Middle Holocene: component 3

Following the hiatus, component 3 dates to around 5900–4500 cal BP (Table 3). The early part of this component includes hearths and some lithic material, which is not as dense as component 4. Density increases over time until reaching the site's second highest density of 108 proximal flakes per 5-cm level and 48 per century (Table 2, Fig. 5). All six lithic sources were consistently used (Castro, 2015). Up until this point, proximal density and source diversity co-varied, reflecting the anticipated pattern for occupational intensity of mobile hunters, but from this point on, they do not. Compared to earlier components, there were lower densities but a much higher a diversity of unifacial and bifacial lithic tools such as retouched knives, spokeshaves, denticulates, projectile points, and scrapers (Cortegoso, 2014, pp. 224). Many are simpler than tools in earlier components. Flake quantity is lower whereas the number of instruments increases, suggesting that more stages of tool production took place outside the rock shelter and the diversity of activities increased.

Lithic data suggest that groups reduced their focus on hunting and incorporated more diverse activities during longer visits (Gasco, 2014; Castro, 2015). The floor was dug out and then rocks were placed to form a wall that partially enclosed the rock shelter. Activities took place in the structure interior, which had a different matrix with higher artifact densities, especially near the hearths. Beginning with this component, there are a number of camelid bones that are morphometrically similar to those of modern llamas, suggesting that herders brought domestic animals to the site (Gasco, 2013, 2014). These identifications are more reliable than previous studies in the Andes because they are based on a significantly expanded reference collection of modern camelids. There was also a bone tool made from a camelid metapodial similar to those use by modern pastoralists for weaving. Data from component 3 reflect longer stays by herders with more diverse activities, which clearly contrasts with shorter stays by more mobile hunters in components 4–5.

5.5. Late Holocene: components 1–2

The final two components of the site indicate an intensification of the pattern from component 3. The use of space is similar, with a higher density of ash, hearths, and pits. Another two structures were built. Lithic density is low but steady, just 10 proximal flakes per century (Table 2). There is a shift to making more instruments, which are much more expedient, mostly based on edge retouch. Instruments are more frequent than in any other component. Despite lower overall densities, source diversity remains high, with 5–6 sources represented in most levels (Castro, 2015).

Much better preservation of bone and macrobotanic remains offer a richer picture of cultural practices, some of which may be conservative traditions that extend to earlier components. There is a more diverse set of fauna that includes birds, rodents, and small mammals, in addition to the dominant signature of Artiodactyla and Camelidae that is present throughout the site (Gasco, 2014, Table 4). Domestic camelid bones are increasingly common. In component 1, very good preservation made it possible to identify the species of 53 camelid bone specimens (Gasco, 2013, Table 9.1, 2014, Fig. 5), showing that there were more wild than domestic camelid bones. Hence, even though these groups were taking llamas to pasture, hunting remained an important activity, especially near high-altitude *vegas*. Mobility patterns centered around taking animals to pasture, going to productive hunting areas, and visiting a variety of lithic raw material sources.

Ethnobotanic macro-remains are scant until component 1, due to poor preservation (Gasco, 2014 pp. 179–182; Llano and Fernández, 2014, Fig. 3). There is a variety of plants, mostly local, which would have been useful as dyes, construction materials, animal fodder, medicine, fuel, and food. Some edible plant remains had indications of processing. Seasonally-specific plant parts confirm that the site was used during the summer. One notable find was a sleeping mat made of *Deyeuxia* grasses (Llano and Fernández, 2014, pp. 166–167). Many of the plants are locally available, but others such as *Geoffroea*, *Prosopis*, *Berberis*, and *Chusquea* are from the western slope of the Andes, suggesting that people moved between ARQ-18 and the Pacific coast (Llano and Fernández, 2014, pp. 159). This mobility pattern may have begun earlier. Overall, the later components suggest longer stays and a much more diverse set of activities, which is notably different from earlier occupations that were shorter and more focused on projectile-point production.

5.6. Regionally-known projectile point styles

Excavations revealed projectile points made in regionally-known styles, which can suggest the origin or movements of groups who occupied the site. Specific types can be useful as a starting point for discussing connections between people in different regions (Martínez, 2003). In this spirit, we present an preliminary interpretation based on admittedly sparse data, which hint at macro-regional connections at ARQ-18 to be explored in the future.

In the earliest part of the site, component 5 includes small triangular projectile points which were found just few centimeters above a carbon sample dated to 9400 cal BP (LP-1859, Appendix B, Table 4; Cortegoso et al., 2012b; Castro, 2015). These are stylistically similar to the Tuina style known from the Andean highlands in northern Chile and Argentina. The north–south distribution of Tuina points is 21–26°S at sites dated to 13,000–9500 cal BP, including the earliest highland sites (Fig. 5; Aguerre et al., 1973; Fernández Distel, 1974; Aschero, 1984; Núñez and Santoro, 1988; Aschero and Martínez, 2001; Núñez et al., 2002, 2005; Grosjean et al., 2005; Martinez, 2007; Hocsman et al., 2012; López and Restifo, 2014). Some Tuina points have been found in association with late Pleistocene fishtail points, suggesting that the styles temporally overlapped. Tuina points are darts with non-stemmed bases made to be shot from atlatls. They were probably made to be used in open spaces by lone hunters who traveled long distances (Aschero and Martínez, 2001; Martinez, 2007; Restifo, 2013). The Tuina points from ARQ-18 are located at the end of this temporal range and at 29.5°S, roughly 400 km farther south than other highland sites with similar points. This is consistent with the trend of a southward movement of people using this style over time. The presence of these points makes it likely that hunters from the northern highlands, not the coast, were the first to occupy ARQ-18 who used similar point styles, lithic technologies, and hunting strategies. These would have been effective because the environment is very similar and the camelids would have been plentiful. If this is correct, then future research between 26 and 29°S should reveal similar high-altitude sites with early Holocene contexts and Tuina points, especially in humid, valleys similar to Las Taguas.

Table 4
Early to middle Holocene projectile point styles for the southern Andes (22–32°S) (De Souza, 2004; Mena, 1984; Nuñez et al., 2010).

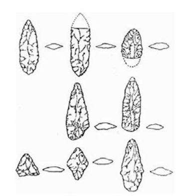
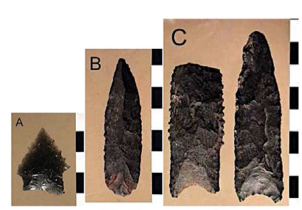
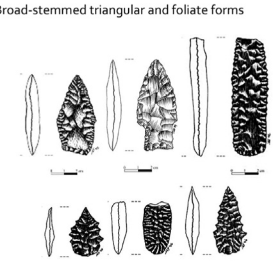
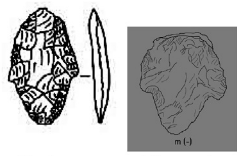
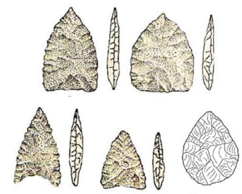
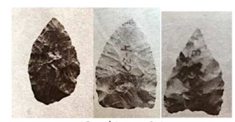
	Late Pleistocene–early Holocene	Early mid-Holocene	Late mid-Holocene
Northern Chile 22–24°	Unstemmed triangular forms (Tuina)  (Núñez et al., 2002, 2010; Hocsman et al., 2012)	• Stemmed triangular points with concave bases • Unstemmed foliate points  (De Souza, 2004)	Unstemmed foliate and rhomboid forms with angular to round shoulders  (Mena, 1984)
Northwest Argentina 23–26°	Unstemmed triangular forms with straight bases  (Martínez, 2003)	• Triangular broad-stemmed points • Contracting to parallel-sided foliates • Lanceolate forms with concave bases  (Martínez, 2003)	• Stemmed triangular and pentagonal forms • Unstemmed edge-modified foliates with straight to contracting stems and convex bases • Broad-stemmed triangular and foliate forms  (Hocsman, 2006, 2014)
ARQ-18 29.5°S	Unstemmed triangular points with straight bases  (Castro, 2015)	Unstemmed points  (Castro, 2015)	• Stemmed pentagonal forms • Ovo-triangular forms  (Castro, 2015)

Table 4 (*continued*)

	Late Pleistocene–early Holocene	Early mid-Holocene	Late mid-Holocene
Norte Chico Region, Chile ~30–31°S	Spine-shoulder foliate points (Huentelauquén complex)  (Jackson, 1997; Alé, 2014)	• Unstemmed triangular points with straight, concave, and convex bases • Ovo-triangular forms  (Ampuero Brito and Rivera, 1971; Alé, 2014)	
Province of San Juan, Argentina ~31.5°	Stemmed and unstemmed foliate points (La Fortuna)  (Gambier, 1974)	Unstemmed triangular points with straight to convex bases (Los Morillos)  (Gambier, 1985)	

The northern connection seems more likely because point styles south of ARQ-18 were very distinct and probably unrelated, known as the Huentelauquén Complex near the Pacific coast (Ampuero and Rivera, 1971; Gajardo, 1986; Jackson, 1997; Méndez, 2002; Alé, 2014) and as La Fortuna in the Argentine highlands (Gambier, 1974). These are large, very thick lanceolate points with stemmed bases that were likely used as spear points for hunting large game. Neither of these styles is present at ARQ-18 (Castro, 2015), nor are there any clear examples at sites north of 30.3°S. The apparent stylistic division between point styles north and south of ARQ-18 reinforces the site's connection to the northern Tuina style.

This interpretation my be refined by ongoing debates over the distribution and chronology of these early projectile points (see Grosjean et al., 2005), including the points from the site San Pedro Viejo de Pichasca (30.3°S). There are Tuina-like points at the site (Ampuero and Rivera, 1971), but they are from the earliest levels, which have poor chronological and stratigraphic resolution. The mid-Holocene levels have better resolution and include points similar to Los Morillos points from San Juan, Argentina (Méndez and Jackson, 2008; Stehberg et al., 2012). Los Morrillos triangular points are of various sizes and shapes and were used from the Pacific coast to the Argentine highlands (Table 4). The points and associated micro-scrapers and micro-perforators were made with careful reduction and regularization techniques (Ampuero and Rivera, 1971; Gambier, 1985; Alé, 2014). Hence for the moment it seems there were two distinct technological early Holocene point styles, with an apparent spatial division at roughly 30°S, somewhere between ARQ-18 and San Pedro Viejo de Pichasca.

At the end of the early Holocene, there are two points in component 4 that suggest connections north and perhaps west of site. There is one small triangular point similar to the northern Tuina points, suggesting a continuity in this style from component 5, though similar points may have also been used to the west near San Pedro Viejo de Pichasca. The second point is a preform of a large lanceolate point, similar to spear points also used in the north. Both point types were in used north of ARQ-18, which were made as atlatl darts and spears, respectively (Pintar, 2009a, 2009b). Perhaps groups from both the north and west used the site.

After the occupational hiatus, ARQ-18 was reoccupied by people who made different points and had different lithic production practices. Some of the points are comparable with the diverse set of points used by herders in northern Argentina (Hocsman, 2014; López and Restifo, 2014). These points are quite diverse, especially in transitional contexts as people shifted from hunting to herding (Aschero and Martínez, 2001; Hocsman, 2006; Martinez, 2007; Pintar, 2009a; Aschero and Hocsman, 2011). This component also included a very large triangular point in the Los Morrillos style, which may be a very northern and late example of this style. Alternatively, the raw material, patinated surface, and edge reworking suggest that it may be a reclaimed and curated artifact (Schiffer, 1987). In this case, it would likely be from an older site located to the south. The few projectile points suggest that ARQ-18 was occupied by groups from the north and perhaps west as hunting gave way to herding.

6. Discussion: correlations between human mobility decisions and climate change

This section seeks to integrate the climate and archaeological chronologies presented in the previous two sections. The focus is on times of pronounced change, which were synchronous in many cases (Fig. 5). These inflection points are key to understanding the human response to local and regional climate change.

6.1. Late Pleistocene glaciers and early Holocene colonization of the high Andes

In the Late Pleistocene, there were human groups living on the coast of Chile, but for a few thousand years they did not intensively occupy the Andes. Chronological models of climate data suggest that the Encierro Valley and probably others near ARQ-18 were in the process of deglaciating from 12,700 to 10,700 cal BP. Notably, people did not begin occupying ARQ-18 for centuries, at around 10,100 cal BP, indicating that the decision to go to ARQ-18 was not a simple question of glaciers retreating. A more important factor may have been the significant aridity that extended to at least 10,800 cal BP. At around 10,100 cal BP, ARQ-18's initial occupation correlates well with spikes in sea surface temperature and moisture, which reached its highest point since the late Pleistocene (Fig. 5). This is analogous to the initial occupation of the high-altitude Peruvian Andes, where glaciers also did not present a barrier to colonization, and was correlated with increasing humidity (Rademaker et al., 2014).

Despite ARQ-18's proximity to coastal populations in the early Holocene, the first occupants more likely arrived from the north. There they would have occupied similar highland environments with a conservative and effective hunting technology that included triangular Tuina atlatl darts (Aschero and Martínez, 2001; Restifo, 2013). They would have stayed at temporally and spatially dispersed foci of ecological productivity, water, and hunting potential, including the Las Taguas Valley (Pintar, 2008a). As an excellent summer hunting ground, it continued to be seasonally occupied for the next 1400 years or so, during ARQ-18's component 5, when the climate was humid and productive. During the component's first half, groups were probably exploring and colonizing the region (Borrero, 1995; Franco, 2004; Cortegoso et al., 2012a). This is supported by the fact that few of the local lithic sources were used and that flake densities and stratigraphy were discontinuous. Prior to the site's initial occupation, this type of mobility may not have been possible due to regional aridity and more specifically, longer distances between ecologically productive valleys in the Andes. These distances dropped around 10,000 cal BP, a factor that made it more plausible for humans to explore and colonize the Andes farther south than they ever had before.

This interpretation is coherent with the scenario that during the peopling of the continent, populations occupied coastal areas all along southern South America. The first occupants of southern Peru and northern Chile moved into the moister highlands and hunted with Tuina points (Santoro et al., 2011). These groups occupied the highlands in Chile and Argentina as far south as ARQ-18. A separate population moved farther down the coast, south of the Atacama Desert, and developed their own lithic styles, the Huentelauquén Complex and La Fortuna, as they moved into the highlands of 30–32°S. Current data show a spatial division between northern and southern projectile point styles around 30°S, suggesting a lack of interaction between these two groups during the early Holocene. This scenario is based on the few extant and may change with new information.

6.2. Middle Holocene aridity, increased occupational intensity, and the occupational hiatus

The regional increase in aridity began around 8700 cal BP, according to pollen reconstructions (Fig. 5). This is the same date that marks the boundary between components 4 and 5 of ARQ-18 (Table 3). Increasingly arid conditions, which would have been especially intense in the lowland summers, inspired new mobility decisions. Occupational intensity in the Las Taguas valley spiked to unprecedented levels in component 4. The dry coastal summers would have made ecorefugia more attractive and groups would have made longer stays at places such as the Las Taguas Valley. Despite longer stays, the lithic data suggest that visitors still had a high degree of mobility. This pattern is consistent with increasing long distances between camps as the regional climate became more arid. The sharp spike in occupational intensity was probably created by larger and more diverse groups. Longer stays by larger groups from different areas may have led to the formation of macro-bands, as proposed for an analogous situation in northern Argentina (Pintar, 2008a, pp. 51–54, 2009a, 2009b). With larger groups, hunting technologies and strategies became more diverse as both atlatls and spears were used (Pintar, 2009a). At ARQ-18, there is one triangular point that would have been used with an atlatl and one lanceolate perform that would have been used with a spear. In both regions, the cause of these lithic and demographic changes may have been increasing aridity and distance between ecorefugia. Given these similarities, the better-documented pattern in northern Argentina for this period may also effectively describe surrounding ARQ-18, a working hypothesis that could be tested with data from excavations at other nearby sites (see Pintar, 2008a; Muscio, 2012; Restifo and Hoguin, 2012; López and Restifo, 2014). This pattern changed drastically at around 7600 cal BP, the transition from component 3 to 4. At around the same time, 7800 cal BP, the period of decreasing aridity gave way to hyperaridity.

During the hyperarid middle Holocene, there was a complete lack of pollen in Pacific coastal records and sharp spike in sea surface temperature. With the previous increase in aridity, occupation became more intense at ARQ-18. However, this level of aridity seems to have crossed a climatic threshold that caused human groups to change their mobility patterns and effectively abandon the site for around 1700 years. This “archaeological silence” is part of a regional pattern that has been documented from the highlands in northern Argentina and Chile as far south as northern Patagonia (Grosjean et al., 2007; Neme and Gil, 2009; Núñez et al., 2013; Yacobaccio, 2013; Barberena, 2015; Méndez et al., 2015).

The regional lack of archaeological data is correlated with regional aridity, which would have increased distances between ecorefugia and forced groups to reorganize their annual rounds or migrate to new areas. The moist Las Taguas Valley would have been an attractive ecorefuge. However, it seems it was located too far from winter residential base camps, which may have become too dry to occupy consistently. That is, the increasing distances between viable camps may have expanded too much to maintain previous mobility circuits and hence excluded ARQ-18 as a seasonal destination. Drier conditions seem to have caused a shift in the mobility circuits, mostly likely to the north, where there was a higher density of high-altitude valleys and ecorefugia at this time (Nuñez et al., 1999; Núñez et al., 2005; Morales, 2011; Mondini et al., 2013; Núñez et al., 2013).

While occupational intensity was severely reduced at ARQ-18, the material record is never completely absent, which may have been discarded by infrequent visits by smaller groups. Groups' collective memories may have not completely forgotten this place, despite a long lapse of infrequent occupation. Perhaps ARQ-18 was on the southern edge of new mobility circuits. This scenario seems likely given the subsequent increase in occupational intensity, which was rapid and intense. Returning groups made use of all lithic raw material sources, suggesting they were not recolonizing an unknown area. They returned at around 5900 cal BP, which is very similar to the date for the renewed presence of pollen at 5700 cal BP. Like in the earliest components, occupational intensity tracks humidity and both return to early Holocene levels.

The different mobility decisions in response to aridity around ARQ-18 may be useful to better understand regional patterns in the middle Holocene. As aridity began to increase, occupational intensity rose drastically. After crossing an environmental moisture threshold, occupational intensity dropped to a minimum. These thresholds may be regional or more local, and additional paleoclimatic data on both moisture and perhaps more importantly, temperature, may be able to better define the relative productivity of ecorefugia and the distances between them. This distance is a quantifiable variable that may reflect the threshold that caused a change in how groups decided to move across the landscape. Ethnographic comparisons of distance between moves may be useful (Kelly, 1995, pp. 112; Pintar, 2008b, pp. 54), though must be considered in the unique Andean case of dispersed and seasonal high-altitude ecorefugia not far from reliable coastal resources. These ecologically-based thresholds for mobility decisions may be important for understanding mobility patterns as groups adjusted their movements through the Andean highlands and adjacent lowlands.

6.3. *Environmental variability and the domestication of camelids (components 1–3)*

Moisture reached a high point at around 5300 BP, after which humidity levels were generally lower than in the early Holocene and more importantly, less stable (Fig. 5). Lithic patterns suggest that people may have responded to this by adding a significant productive practice, herding domestic camelids. The reoccupation of the site may have been from the north, as in the early Holocene, again due to environmental similarities. The domestication process may be a response to environmental instability that allowed herders to expand spatially and demographically after the middle Holocene dry spell (Mengoni and Yacobaccio, 2006; Yacobaccio and Korstanje, 2007; López and Restifo, 2014, pp. 109) principally due to pastoralism's ability to manage risk in unpredictable environments (Browman, 1987; Kuznar, 2001; Restifo and Hoguin, 2012; see synthesis in Gasco, 2013, pp. 17–30; Frigolé and Gasco, in this issue). The decision to change subsistence strategies may be a response to decreasing environmental stability as ENSO frequency increased in the late Holocene (Donders et al., 2008).

The material record is remarkably different from earlier components. Lithics show sustained diversity but major drops in quantity. This may not in fact reflect a such a drastic drop in occupational intensity but a shift in lithic technology. Tool reduction seems to have been taken place outside the rock shelter, unlike in previous components. The construction of structures and the sharp increase in artifact diversity suggest that people were no longer using the site only as a productive hunting camp, but also a herding area. They probably occupied the site for longer periods, and perhaps the whole summer, like modern goat pastoralists in this region (Gambier, 1986; Gasco, 2013, pp. 30–41; Gasco et al., in press). These economic practices become apparent at some point in component 3, though it is difficult to estimate a precise date; they continue uninterrupted through components 1 and 2. Future research at similar sites should excavate and analyze this period with care in order to evaluate the pace of the transition to herding. This important change is difficult to track with the region's current chronological resolution. The long term stability of herding practices owes to human decisions to incorporate domestic animals as a way of reducing risk in the highly variable late Holocene climate.

7. Conclusion

The main goal of this paper was to refine and compare environmental and cultural chronologies around the high-altitude site ARQ-18. These chronologies made it possible to evaluate synchronous changes and potential human decisions made in response to regional climate change. Late Pleistocene to middle Holocene correlations suggest climate-conditioned adaptive decisions that led to different prevailing mobility patterns.

During the late Pleistocene, the Pacific coast of southern South America was colonized by groups advancing rapidly through the continent's Pacific littoral. At this time, many highland environments, including the Las Taguas Valley, were dominated by glaciers and resource-poor. In the early Holocene, retreating glaciers in the highlands ceded to resource-abundant microclimates. After deglaciation, many centuries passed before ARQ-18 was first occupied around 10,100 cal BP, when regional humidity peaked. Hunters ranged as far south as ARQ-18, moving quickly through an environmentally-familiar but uninhabited landscape. Their stays at places such as the Las Taguas Valley were limited to the summer months, which were initially short. As aridity began to increase, groups from various regions shared this space as the site's occupational intensity reached its Holocene maximum. As aridity crossed a significant eco-cultural threshold around 7800 cal BP, coastal sediments became pollen-starved and archaeological material dropped to a minimum. During the ensuing hiatus, mobility circuits effectively excluded the site, which have shifted north. The key factor in moving or adjusting mobility circuits may have been the distance between productive ecorefugia, which should be a focus for future paleoclimatic and archaeological research. Finally, at the end of the middle Holocene, climatic conditions improved and the valley was reoccupied. The region was never as dry again but it became less stable, which was probably a significant factor in the region-wide incorporation of herding, a strategy which may manage risk in the Andes even better then flexible hunter-gatherer mobility, especially in areas with denser populations.

We anticipate that future research will continue to benefit from approaches that closely integrate climate and cultural data, especially if close attention is paid to the scale and resolution of the data sets. Doing so will require refined, calibrated chronologies that take advantage of Bayesian models, which depend on detailed excavation data, especially of contexts that document short periods of rapid change. Additional research from nearby sites will be able to use spatial resolutions that were familiar to the people making decisions to stay in camp or leave for a new area, perhaps to go to another of the Andes' vital highland ecorefugia.

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Appendices

Appendix A
Bayesian model of environmental dates.

	Date or event	Calibrated (cal BP)				Calibrated and modelled (cal BP)				A
		Median	Sigma	68%	95%	Median	Sigma	68%	95%	
	End					50	410	380–170	450–900	
Variable late Holocene	Last Variable late Holocene					290	100	450–150	470–70	
	Hv-16674	270	100	440–140	450–...	290	100	450–150	470–70	96.1
	Hv-17387	650	50	720–560	740–550	650	50	720–560	740–550	99.7
	Hv-16793	810	70	910–730	930–680	810	70	910–730	930–680	99.9
	Hv-17386	1160	80	1270–1070	1300–980	1160	80	1270–1070	1300–980	99.9
	Hv-17378	1760	80	1870–1630	1910–1590	1760	80	1870–1630	1910–1590	99.8
	Hv-17383	2370	220	2700–2150	2760–1930	2370	220	2700–2150	2760–1930	100.0
	Hv-17375	2590	100	2750–2490	2760–2370	2590	100	2750–2490	2760–2370	99.9
	Hv-17379	2670	110	2780–2500	2860–2430	2670	110	2780–2500	2860–2430	99.8
	Hv-17377	3160	110	3330–3060	3360–2960	3120	110	3220–3000	3350–2920	97.1
	First Variable Late Holocene					3120	110	3220–3000	3350–2920	
	Boundary: Middle → late Holocene					3340	210	3520–3100	3820–2990	
Wet middle Holocene	Last wet Middle Holocene					3720	230	3990–3500	4140–3260	
	Hv-16952	3580	330	3900–3230	4250–2890	3730	280	3980–3420	4380–3220	102.3
	Hv-17385	4020	110	4140–3900	4240–3830	4020	110	4150–3900	4240–3830	100.0
	Hv-17388	5110	260	5450–4840	5600–4570	5120	260	5450–4840	5600–4570	100.0
	Hv-17389	5410	110	5580–5310	5590–5070	5410	110	5580–5310	5590–5070	99.9
	Hv-17376	5720	110	5890–5600	5930–5470	5720	110	5890–5600	5930–5470	100.0
	First moist Middle Holocene					5720	110	5890–5600	5930–5480	
Wet early Holocene	End wet early Holocene					7820	490	8180–7530	8300–6540	
	Last wet early Holocene					8120	80	8190–8020	8300–7970	
	Hv-17381	8110	80	8180–8020	8310–7960	8120	90	8190–8020	8320–7970	97.0
	Hv-17701	8290	90	8390–8200	8460–8040	8300	90	8390–8200	8460–8050	100.7
	Hv-17373	9160	240	9460–8990	9530–8640	9160	240	9460–8990	9530–8640	100.1
	Hv-16984	10,340	150	10,500–10,210	10,660–9930	10,340	150	10,490–10,210	10,660–9930	100.0
	Hv-17380	10,640	180	10,780–10,430	11,080–10,290	10,630	170	10,770–10,440	11,070–10,290	102.9
	Hv-16673	10,940	150	11,140–10,780	11,220–10,670	10,880	150	11,030–10,710	11,200–10,590	96.3
	First wet early Holocene					10,900	150	11,060–10,730	11,200–10,650	
	Start wet early Holocene					11,200	430	11,460–10,790	12,260–10,660	
Deglaciation	End deglaciation					10,520	740	11,090–10,120	11,420–8850	
	Last deglaciation					10,720	330	11,070–10,420	11,320–9990	
	EE11	11,600	500	12,100–11,100	12,600–10,600	11,140	360	11,460–10,780	11,930–10,490	87.8
	EE12	11,300	400	11,700–10,900	12,100–10,500	11,100	310	11,390–10,780	11,750–10,500	103.5
	EE24	10,900	500	11,400–10,400	11,900–9900	10,970	340	11,300–10,650	11,650–10,250	117.2
	EE22	10,400	400	10,800–10,000	11,200–9600	10,800	350	11,160–10,480	11,420–10,030	80.5
	First deglaciation					11,270	320	11,560–10,920	11,970–10,680	
	Start deglaciation					11,440	480	11,830–10,940	12,550–10,680	
	Boundary: Glacial maximum → Deglaciation					12,660	650	13,380–11,970	13,820–11,350	
Glacial maximum	Last glacial maximum					13,160	450	13,630–12,710	14,040–12,220	
	EE62	13,100	700	13,800–12,400	14,500–11,700	13,310	510	13,840–12,810	14,340–12,250	110.8
	EE51	13,700	700	14,400–13,000	15,100–12,300	13,500	520	14,010–12,980	14,580–12,470	110.9
	EE34	14,000	600	14,600–13,400	15,200–12,800	13,630	510	14,110–13,100	14,690–12,640	96.5
	First glacial maximum					13,800	490	14,280–13,300	14,830–12,860	
	Start					14,150	1170	14,820–13,290	16,630–12,740	
Spans	Variable late Holocene					2830	150	2670–2980	2540–3140	
	Wet middle Holocene					2000	250	1720–2260	1540–2510	
	Dry middle Holocene					2400	140	2530–2260	2670–2130	
	Wet early Holocene					2780	170	2600–2960	2460–3120	
	deglaciation					510	470	0–780	0–1530	
									A (model)	97.5
									A (overall)	98.5

Appendix B
Bayesian model of archaeological dates.

	Date or event	Calibrated (cal BP)				Calibrated and modelled (cal BP)				A
		Median	±	68%	95%	Median	±	68%	95%	
	End					1190	500	1500–970	1570–0	
Components 1–2	Last 1–2					1460	60	1530–1380	1560–1310	
	LP-2085	1440	60	1530–1370	1550–1310	1460	60	1530–1380	1560–1310	99.9
	LP-2094	1670	80	1720–1560	1820–1540	1670	70	1730–1560	1820–1540	100.1
	LP-1842	1840	90	1930–1730	2000–1620	1840	90	1930–1730	2000–1620	100.0
	LP-1851	2310	100	2360–2150	2490–2140	2310	100	2360–2160	2490–2140	99.3
	LP-1448	3150	100	3330–3030	3360–2960	3150	100	3330–3030	3360–2960	100.1
	LP-1847	4070	90	4150–3980	4250–3890	4050	90	4150–3970	4240–3890	100.6
	First 1–2					4050	90	4150–3970	4240–3890	
	Boundary: 3 → 1–2					4480	270	4750–4140	4980–4000	
Component 3	Last 3					4920	140	5050–4820	5240–4630	
	LP-1973	4900	150	5050–4720	5280–4580	4920	150	5220–4740	5290–4620	99.7
	LP-1972	5150	150	5320–4980	5460–4860	5160	150	5320–4980	5470–4860	100.4
	LP-1854	5610	100	5720–5480	5880–5330	5610	100	5720–5480	5880–5330	100.0
	LP-1840	5850	80	5930–5750	6000–5720	5850	80	5930–5750	6000–5720	99.9
	First 3					5850	80	5930–5750	6000–5720	
Component 4	Last 4					7560	70	7630–7470	7690–7420	
	LP-1976	7560	70	7630–7470	7690–7420	7560	70	7630–7470	7690–7420	99.9
	AA-18731	7780	100	7930–7670	7970–7590	7780	100	7930–7670	7970–7590	100.3
	LP-1857	8120	90	8190–8000	8330–7960	8110	90	8190–8010	8320–7960	100.7
	First 4					8110	90	8190–8010	8320–7960	
	Boundary: 5 → 4					8740	310	9140–8450	9240–8130	
Component 5	Last 5					9070	170	9270–8900	9320–8650	
	LP-1977	8970	210	9240–8710	9400–8590	9080	200	9300–8860	9430–8650	95.2
	AA-18732	9230	90	9370–9120	9420–9030	9240	90	9400–9130	9420–9030	100.3
	LP-1859	9400	100	9510–9300	9540–9130	9400	100	9500–9300	9540–9130	100.5
	LP-1860	9440	110	9540–9310	9580–9130	9440	110	9540–9310	9590–9130	100.4
	LP-1815	10,040	150	10,230–9910	10,260–9690	9920	170	10,070–9690	10,220–9560	76.7
	First 5					9920	170	10,070–9690	10,220–9560	
	Start					10,100	390	10,330–9750	10,920–9560	
Durations (Differences)	Component 1–2					3350	580	2810–3730	2550–4590	
	Component 3					1370	280	1070–1690	840–1880	
	Component Z (hiatus)					1710	100	1810–1600	1910–1510	
	Component 4					1180	320	860–1570	530–1700	
	Component 5					1400	550	820–1860	460–2520	
Spans	Span 1–2					2600	110	2490–2710	2390–2830	
	Span 3					930	160	780–1080	590–1270	
	Span 4					550	120	430–670	330–810	
	Span 5					860	260	570–1110	370–1380	
									A (model)	93.3
									A (overall)	93.3

Appendix C. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.quaint.2015.12.011.

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