Projectile point variability from a biogeographical approach in northwestern Patagonia, Argentina

Fernando Franchetti¹, María de la Paz Pompei², and María Laura Salgán¹

¹ Institute of Evolution, Historical Ecology and Environment (IDEVEA), National Scientific and Technical Research Council (CONICET), National Technological University Universidad Tecnológica Nacional (UTN), San Rafael; Department of Archaeology, Faculty of Philosophy and Letters, National University of Cuyo, Mendoza, AR; ffranchetti@mendoza-conicet.gob.ar; mlsalgan@mendoza-conicet.gob.ar
² Higher Institute of Social Studies (ISES), CONICET, National University of Tucumán, San Miguel de Tucumán, AR; mpompei@mendoza-conicet.gob.ar

ABSTRACT - Our objective is to analyse the relationship among the availability, selection, and use of raw materials suitable for knapping with projectile points from the Late Holocene of northwestern Patagonia. We analyse differences in the raw material used to make projectile points according to the techno-morphological characteristics. Non-stemmed projectile points predominate in all the biogeographic units. The size and weight of the projectile points in Patagonia duplicate those from Altoandina and Monte. We conclude that there was a coexistence of two weapons systems related to hunting, the bow and arrow, together with the use of darts.

KEY WORDS - lithic tools; projectile points; biogeography; rock selection; hunting strategies

Introduction

Projectile points and their morphological types have been traditionally used as temporal markers to establish a relative chronology in the archaeological record (Bird 1993; Martínez 2003; Belardi et al. 2005). Projectile points (PP) are an essential part of several weapons systems. Beyond their technological variations and particularities, they are present throughout the Holocene until the Spanish contact. In the Late Holocene, there was an increase in the use of obsidian and tools made of this raw material, mainly with regard to the manufacture of PP (Durán 1997; Gil 2006; Neme 2007; Neme, Gil 2008; Cortegoso et al. 2012). In southern Mendoza, stemmed projectile points named Fortuna (Gambier 1980) belong to Early and Middle Holocene contexts. Triangular projectile points, called Morrillos, are associated with late occu-
projectile points (Gambier 1980). Both morphologies of projectile points coexisted in the Late Holocene.

In this paper, we present the study of PP from archaeological sites of three biogeographic units from southern Mendoza: Altoandina, Patagonia, and Monte (Fig. 1.a; Salgán et al. 2022). Our objective is to test differences and similarities in the use of raw materials to manufacture PP from their techno-morphological characteristics. In addition, we explore if there was a particular selection of obsidian sources to make PP in each biogeographic unit, specifically during the Final Late Holocene. In this context, changes in hunting strategies generated the need to manufacture PP of smaller size and volume. Therefore the use of obsidian presented advantages compared to other tool stones. Finally, we assess a first approximation to interpret the hunting strategies according to raw material use and PP characteristics in each environment.

**Projectile points in the archaeological studies of southern Mendoza**

In the Diamante and Atuel rivers (Franchetti 2019; Pompei 2019) and El Payén area (Fig. 1.a,b; Salgán 2013), we have already characterized the spatial distribution, availability, and properties of raw materials. These studies addressed the use of raw materials in each environment, the possible mobility circuits, as well as changes and continuities in the lithic organization (Salgán et al. 2014a; Franchetti 2019; Pompei 2019; Salgán et al. 2022).

In the Diamante river (Fig. 1.b), Fernando Franchetti (2019) observed a predominant use of basalts in the surface archaeological assemblages, followed by cryptocrystalline rocks, obsidian, and other rocks. Hunter-gatherers acquired basalts from primary and secondary sources. The Diamante valley has localities with cores and flakes with cortex, indicating active access and use of basalts. In addition, all the metric variables for this raw material are larger in the Patagonia unit, in contrast to the sizes in the Altoandina unit. There was direct access to this raw material in the lower zones, with seasonal and year-round posterior conveyance to the highlands. In the Patagonia unit, Franchetti (2019) observed a contrast in the abundance of scrapers in the larger sites compared to base camps in the Altoandina unit. In this last environment, we found PP mostly as isolated findings and in secondary base camps related to hunting practices. In the Altoandina unit, there are also localities with cores and evidence of the early stages of reduction in cryptocrystalline rocks. The use of other rocks of lower quality, such as rhyolites and vulcanites, is sporadic and opportunistic. The only non-local raw material is obsidian, registered at a 40km distance or further from the archaeological sites (Meltzer 1989). The nearest source is Laguna del Diamante, and this location has the lowest frequency among the known obsidian sources detected in the lithic organization of the Diamante valley (Franchetti et al. 2022). Obsidian predominates in the larger sites, mainly as PP and bifaces (Franchetti 2019).

In stratigraphic sites from the Atuel river, María de la Paz Pompei (2019) noted a higher use of cryptocrystalline rocks, followed by obsidian, basalt, and other raw materials (Fig. 1.b). Obsidian in the Atuel valley is also non-local, since the known sources are further than 40km away (Civalero, Franco 2003). The other raw materials are available along the river in the three biogeographic units as primary and secondary sources (Pompei 2019). In the Atuel valley archaeological record, cryptocrystalline rocks predate in the Patagonia and Monte units, followed by obsidian. In the Altoandina unit, the use of obsidian predominates followed by cryptocrystalline rocks. Therefore, hunter-gatherers selected the best quality raw material available for knapping – both spatially and temporally – in each unit. The Monte sites also show the use of rhyolites and other rocks of lower quality. In the Atuel valley, hunter-gatherers mostly used obsidian to make PP and other bifacial tools. In contrast, hunter-gatherers used cryptocrystalline rocks to make unifacial tools. However, in the Patagonia unit, there are numerous PP made of cryptocrystalline rocks. There is low use of basalts to make tools, but there are some unifacial and bifacial tools. In burials, there is evidence of PP made of rhyolites and vulcanites. Other technological trends observed in the Atuel valley include the scarcity of cores to transport rocks, the low or non-existent presence of cortex, and the scarce proportion of the initial stages of the reduction sequence (Pompei 2019). There may be a sample bias in the assemblages, which all belong to large excavated sites and a portion of their stratigraphic record.

In the Payén area, Laura Salgán (2013) analysed lithic assemblages from surface and stratigraphic sites. In this location, cryptocrystalline rocks predominate, followed by obsidian, basalts, and other raw materials (Fig. 1.b). The results suggest exploitation of local rocks, such as cryptocrystalline and non-local obsi-
dian, available in the north and centre of the area (Salgán 2013). The strategy of cryptocrystalline rock procurement presents scarce preparation techniques, evidence of conveyance of base forms, and, in lower frequency, cores (Salgán 2013). Hunter-gatherers used and discarded formal tools without evidence of fractures. In contrast, obsidian appeared as bifacial tools, mostly in fractured states. Salgán (2013) considered local raw materials within a range of 40km as local, and thus sources beyond this radius as non-local. The use of local basalts and rhyolites to make tools was occasional. Obsidian can be considered non-local, except for Laguna del Maule 2 and Cerro Huenul, located less than 40km from archaeological sites south of the Payén area (Salgán 2013).

**Regional lithic resource base in Altoandina, Patagonia, Monte**

The characterization of the lithic resources regional base (LRRB), in conjunction with petrographic and geochemical studies on rocks, provides relevant information to advance the comprehension of technological strategies adopted by human societies (Ericson 1984; Nelson 1991; Aragón, Franco 1997; Franco, Aragón 2004; Berón 2006). This approach generates a framework for expectations regarding the distribution, availability, accessibility, and abundance of raw materials in a given area or region. This information is crucial to understand the procurement modes, transport, and utilization of rocks - allowing us to discuss mobility patterns, action ranges, and possible interactions with other human populations (Binford 1979; Lyons et al. 2003; Franco 2004).

We generated the LRRB of southern Mendoza from three complementary lines of information (Salgán et al. 2022): (1) bibliographic revision of the geologic and lithologic characteristics of the different environmental units, which allowed us to estimate the distribution and localization of potential sources of raw materials suitable for knapping; (2) a targeted survey of geologic formations and sampling of rocks close to water courses, following the geological and archaeological background (e.g., Gambier 1980; Lagiglia 1997; 2002; Durán 2000; Gil 2006; Neme 2007), which made it possible to establish the availability, quality, relative abundance, variability and accessibility of raw materials suitable for knapping (Torrence 1989); and (3) petrographic analysis of cryptocrystalline outcrops (Salgán et al. 2014b) and determinations of obsidian nodules from known sources and samples from archaeological sites and collections. This approach improved the knowledge of the genesis of such tools, geological characteristics, and preferred locations (Giesso et al. 2011; Cortegoso et al. 2012; Salgán et al. 2012, 2020; Barberena et al. 2019).

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**Fig. 1.** a Biogeographic units and archaeological sites with lithic assemblages (black dots). b Lithic resources regional base from southern Mendoza. Basalt formations are in dark grey.
Salgán et al. (2022) divided southern Mendoza into three biogeographic units associated with phytogeographic provinces – Altoandina, Patagonia, and Monte (Cabrera 1976; Oyarzabal et al. 2018) – to test the use of lithic resources and their possible connectivity among the biogeographic units (Nelson 1991). The unit Altoandina includes the Andes cordillera, with altitudes of 2200masl (Neme, Gil 2012). Raw materials have seasonal accessibility, and are predominantly sedimentary rocks of marine origin (sandstones, silicified sandstones, and conglomerates, among others) and igneous rocks (basalts, rhyolites, andesites, basandesites, obsidian, and tuffs) (Nullo et al. 2005; Sepúlveda et al. 2007).

Many of these rocks required transport through the hydric basin that runs west to east, such as along the Diamante, Atuel, Salado, Malargüe, and Grande rivers. Salgán et al. (2022) documented different obsidian primary sources of excellent quality for knapping with four geochemical signals.

(1,2) Laguna del Diamante and Arroyo Paramillos in the Diamante volcanic complex (34° south latitude) (De Francesco et al. 2006; Cortegoso et al. 2020), present small nodules of variable quality; the radii of use ranges 40–100km in linear distance between the source and the sites, especially towards the west side of the Andes cordillera (Cortegoso et al. 2020).

(3) Las Cargas, next to the volcanic complex Ptero and El Cura stream (35° south latitude) (Salgán et al. 2015), presents excellent quality for knapping in an area of 1km², expanding its availability area downstream due to the action of glaciers. This source presents the highest record of use across central western Argentina in sites at distances of 40 to 100km, with evidence of transport beyond 300km (Giesso et al. 2011; Cortegoso et al. 2012; Nami et al. 2015).

(4) Laguna del Maule, located in the homonymous volcanic complex (between 36° and 37° south latitude) (Seelenfreund et al. 1996; Dunin et al. 2004), presents two geochemical subtypes, Laguna del Maule 1 and Laguna del Maule 2 (LM1 and LM2, respectively) (Barberena et al. 2019). These sources differ in their accessibility and availability, but are of excellent quality for knapping. LM1 outcrops as lava flows and blocks in Altoandina, while LM2 appears as nodules transported through the Barrancas and Colorado rivers in the piedmont. LM1 presents a higher use in the 40–100km distance range to sites, with evidence of transport beyond 200km. In contrast, LM2 presents more substantial evidence of local use within the 0–40km range, and less evidence of transport (Barberena et al. 2019).

The Patagonia unit includes the Andean piedmont (2200 and 1200masl) and the volcanic field La Payunia. The rocks are available annually and present high variability. In the north centre of the unit, between the Diamante and Atuel rivers, sedimentary rocks and deposits predominate (Sepúlveda et al. 2007), with scarce rocks of volcanic origin, mainly olivine basalts and basaltic breccias (Nullo et al. 2005). In the south, there are rocks which are the product of the retro arc volcanic complex La Payunia, integrated with olivine basalts, ignimbrites, tuffs, and trachytes (Narciso et al. 2001), and cryptocrystalline rocks of hydrothermal and sedimentary origin (Salgán et al. 2014b). The sampling of raw materials in the Patagonia unit (Salgán et al. 2022) indicates sources of cryptocrystalline rocks (Durán 1997; Campos et al. 2006), the obsidian source Coche Quemado (Salgán et al. 2020), and basalt (Durán 1997; Neme et al. 2011; Salgán et al. 2022).

In the south of La Payunia, the geologic information (González Díaz 1972; Narciso et al. 2001) and the petrographic studies on quarries, archaeological materials, and potential sources indicate a high occurrence of cryptocrystalline rocks, as nodules of diagenetic origin (Salgán 2013; Salgán et al. 2014b). In this biogeographic unit, there are two geochemical signals for obsidian sources: El Pecho (with subtypes El Pecho-1 and El Pecho-2), located in the eastern plains, next to the Monte biogeographic unit (Salgán, Pompei 2017); and Coche Quemado, registered in the middle course of the Grande river, next to El Payén (Salgán et al. 2020).

The Monte biogeographic unit covers the east of the extra-cordilleran plains, with an altitude below 1200masl (Fig. 1.a). This unit has eolian and alluvial sediments which form the eastern plain (Sepúlveda et al. 2007). Some hills interrupt the landscape, with a lithology composed of andesites, trachyandesites, basalts, rhyolites, obsidian, and dacites (Sepúlveda et al. 2007). In the samplings done in the eastern portion of the Atuel river, there are rhyolites and cryptocrystalline rocks of good to excellent quality for knapping, available as secondary sources (Pompei 2019, Salgán et al. 2022). Although these rocks have diverse qualities and are available throughout the
year, there is generally limited access to them. This is likely due to the small nodules and low visibility related to vegetation cover and sediment deposits.

**Projectile points from a biogeographical approach**

PP present an identifiable morphology and are recurrent in the archaeological record, and offer analytical possibilities that other artefacts do not have (Fig. 2). PP are a complex technology, their design and maintenance were influenced by cultural norms (Knecht 1997), the necessity for reliable tools (Bleed 1986), functional efficiency (Smith 2015), provisioning strategies (Thomas 2012), and the quality and availability of raw materials (Smith 2015). There are various advantages with regard to using PP in lithic studies: (1) morphological types can provide relative chronology (Thomas 1981); (2) they provide indirect evidence of prehistoric subsistence strategies, including when there are no faunal remains (Hockett, Murphy 2009); (3) they allow the reconstruction of foraging areas or exchange networks thanks to their link to specific geological sources (Smith 2015); (4) they make it possible to infer weapons systems, which combined with other factors such as topography and prey ethology, can generate models of hunting strategies (Martínez 2003; 2007).

In central western Argentina, the studies centred on the analysis of PP focused on the interaction between agricultural and hunter-gatherer societies (Castro et al. 2018). In southern Mendoza, the related PP studies examine their use as chronological markers (Lagiglia 1977; 1997; Gambier 1980), as part of regional studies (Durán 1997; Gil 2006; Neme 2007), or engage in technological analysis from a biogeographic perspective (Salgán 2013; Franchetti 2019; Pompei 2019).

**Materials and methods**

The PP analysed in this study belong to samples from the Diamante river (Franchetti 2019), the Atuel valley (Pompei 2019), and El Payén (Salgán 2013) (Figs. 1 and 2). We studied 203 PP from the Altoandina (37%, n=75), Patagonia (51%, n=103) and Monte (12%, n=25) biogeographic units. The sample includes artefacts from surface recollections (isolated findings and archaeological sites), systematic random sampling of the surface, and excavations of base camps and burials.

The analysis of PP did not include preforms and followed a techno-morphological approach (sensu Aschero 1975; 1983). The variables selected are: raw material, presence or absence of stem, and state of fragmentation (entire or fractured). For the entire pieces, we measured length, width, and thickness in millimetres, according to the morphological axis (sensu Aschero 1975; 1983), and weight in grams. This last measure avoids the redundancy in the size measures and allows us to estimate the relevance of each raw material. We counted the segments present for the fractured pieces, following these categories: tips, tip-mesial fragments, mesial fragments, basal-mesial fragments, and basal fragments (in both stemmed and non-stemmed PP) (Martínez 2003; Belardi et al. 2005). We measured the maximum width and thickness for basal-mesial, stem, and basal fragments. In the entire PP, we calculated volume in mm$^3$, multiplying length, width, and thickness, then dived by 100.

To avoid an oversized sample we calculated the minimum number of PP required for the analysis (Belardi et al. 2005), which considers the frequency of all the PP, summing fragments of basal-mesial and basal fragments. In addition, we calculated the manufacture and replacement index from Daniel S. Amick (1996), as obtained by the quotient between basal plus mesial fragments, and tips plus mesial fragments in each unit. This allows us to estimate and compare which biogeographic
unit had more or less discard and replacement of PP. In addition, we calculated the production index, obtained by dividing the total PP by the total number of tools (Salgán 2013). We also calculated the functional adscription of the PP, in an exploratory approach, following Michael J. Shott (1997) and Jorge G. Martínez (2003), which makes it possible to differentiate between the form of propulsion and weapon system present in the archaeological record (Ratto 1991; Shott 1997; Martínez 2003). In particular, we used the classification for weight from Martínez (2003), in which ranges from less than 4 grams for arrows, to between 4 and 20 grams for darts, and between 21 and 70 grams for spears (Martínez 2003; Heider, Rivero 2018).

We complemented these measures with the analysis of the discriminant function, which uses linear dimensions from PP, calculated through equations to differentiate arrows from darts (Thomas 1978; Shott 1997; Castro et al. 2018; Heider, Rivero 2018). We considered the maximum width to apply the Shott (1997) functions. We determined darts using 1.4 multiplied by the maximum width minus of 16.85. On the other hand, we determined arrows using 0.89 multiplied by the maximum width minus of 7.22. We compared the results from both equations and made a functional assignment according to the higher results. When it was possible to distinguish between final and initial Late Holocene samples, we compared the raw materials used to make PP.

Results

**Discriminant analysis of lithic projectiles**

The results for the raw materials selected to produce stone tools in the Altoandina, Patagonia, and Monte biogeographic units indicate that in all of them the use of cryptocrystalline rocks predominates (Tab. 1). This is most evident in Monte (80.6%), followed by Patagonia (60.9%), and Altoandina (43.1%). The second type of rock with the highest use for stone tools varies among the biogeographic units: in Altoandina and Patagonia it is basalt (37.1% and 18.5%, respectively), while in Monte it is obsidian (14.8%). The results for raw materials selected to produce PP show that in Altoandina and Patagonia the use of obsidian to make PP predominates, followed by basalt in Altoandina, and cryptocrystalline rocks in Patagonia (Tab. 2). Figure 1 highlights the presence of basalt in southern Mendoza. However, sampling in the field showed differences in the quality for knapping among the biogeographic units (Salgán et al. 2022). In Altoandina the samples presented very good to moderate quality, while in Patagonia and Monte they were mainly of lower quality, being good to regular (Salgán et al. 2022). In Monte, the use of obsidian as the second common raw material occurs due to the scarcity of knapping rocks in the landscape. In this area, we observed 2.9% of other raw materials and 1.6% of basalt use (Tab. 1).

In Altoandina and Patagonia, the third raw material used is obsidian, available in both environments as primary sources, and in Patagonia also found as a secondary source. This indicates a significant influence of the LRRB in the selection of rocks to make PP. In Altoandina and Patagonia the best rocks available are the most used. In contrast, in Monte, with a lack of quality rocks, the lithic resources recorded as the second most used are the best raw material available in the neighbouring areas. An example is the obsidian from El Pecéno located in Patagonia, seen in the assemblages of Monte (Salgán, Pompei 2017; Pompei 2019). In addition, Monte shows the highest variety of rocks used to manufacture tools.

<table>
<thead>
<tr>
<th>Raw Material</th>
<th>Altoandino</th>
<th>Patagonia</th>
<th>Monte</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>Cryptocrystalline</td>
<td>18</td>
<td>24</td>
<td>22</td>
</tr>
<tr>
<td>Obsidian</td>
<td>30</td>
<td>40</td>
<td>71</td>
</tr>
<tr>
<td>Basalt</td>
<td>27</td>
<td>36</td>
<td>10</td>
</tr>
<tr>
<td>Others</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>75</td>
<td>100</td>
<td>103</td>
</tr>
</tbody>
</table>

**Tab. 1. Frequencies and percentages of artefacts by raw material in each biogeographic unit.**

<table>
<thead>
<tr>
<th>Raw Material</th>
<th>Biogeographic unit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Altoandino</td>
</tr>
<tr>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>Cryptocrystalline</td>
<td>1980</td>
</tr>
<tr>
<td>Obsidian</td>
<td>651</td>
</tr>
<tr>
<td>Basalt</td>
<td>185</td>
</tr>
<tr>
<td>Others</td>
<td>105</td>
</tr>
<tr>
<td>Total</td>
<td>2921</td>
</tr>
</tbody>
</table>

**Tab. 2. Frequencies and percentages of projectile points by raw material in each biogeographic unit.**
Table 3 shows PP by biogeographic units, raw material and state of fragmentation (entire or fractured). The PP are either fractured (62%) and entire (38%). The tips, mesial fragments, and tips-mesial fragments have higher frequencies in Altoandina and Patagonia compared to Monte. We calculated the minimum number of PP from the available fragments, which is 139, 68% of the PP (Tab. 3).

The main raw material used for PP in Altoandina and Patagonia is obsidian, and for Monte it is cryptocrystalline rocks (Fig. 3.a). In Altoandina, basalts and cryptocrystalline rocks are used equally to make PP as the second most common raw materials. In Patagonia, cryptocrystalline rocks and basalts were the second and third most common raw materials used to make PP, respectively. In Monte, cryptocrystalline rocks were the most often used to make PP, followed by obsidian, basalts, and other raw materials (vulcanites and rhyolites).

The analysis of entire PP and fragments with a base allowed us to separate the sample according to the hafting area, in non-stemmed PP or bases without a stem (n=98) and stemmed PP (n=41). In Figure 4, we observed a more significant frequency of non-stemmed PP in Altoandina (n=50), especially those made of obsidian, basalt, and cryptocrystalline rocks. In Patagonia, we observed non-stemmed PP made of obsidian, basalt, and cryptocrystalline rocks (n=36). In Monte, we observed non-stemmed PP made of cryptocrystalline rocks, obsidian, basalt, and other raw materials (vulcanite and rhyolite) (n=12). In contrast, we observed a higher frequency of stemmed PP in Patagonia (n=33), made of obsidian, cryptocrystalline rocks, and basalt (Figs. 2 and 4). In Monte, there is a low frequency of stemmed PP (n=7) made of cryptocrystalline rocks and obsidian (Figs. 2 and 4). In Altoandina there is only one stemmed PP made of obsidian (Figs. 2 and 4). The discard and replacement index (Amick 1996), indicates that there was more replacement of pieces in Monte (1.7), followed by Patagonia (1.3), and Altoandina (1.2).

Table 4 shows the averages for length, width, and thickness that were used in the volume calculation. In the three biogeographic units, the averages for this variable indicate lower values for PP made of obsidian. In Patagonia and Monte, the PP made of basalt have a higher volume, while in Altoandina the PP made of cryptocrystalline rocks have a higher volume. In Patagonia, the PP of all raw materials have a higher volume compared to those from the other biogeographic units. We observed a similar trend with regard to the weight. Figure 3.b compares the average weight of PP by biogeographic unit, showing a large difference with regard to Patagonia (4.2 ± 1.1g) compared to Altoandina (2.7 ± 0.5g) and Monte (2.7 ± 0.7g) at an 80% confidence level. There are no significant differences in the weight averages between Altoandina and Monte.

To explore changes over time, we selected 32 PP from seven stratigraphic sites (three from Patagonia and Monte, one from Altoandina) from the Atuel river and El Payén area. We aimed to test changes in the use of raw materials between the Initial Late Holocene (ILH) 4000–2000 years BP, and the Final Late Holocene (FLH) 2000–200 years BP (Pompei 2019). Figure 5 shows that in both periods of the Late Holocene PP were mostly made of obsidian, followed by cryptocrystalline rocks. In the FLH there was a higher variety in the rocks used to make PP, with the incorporation of basalt, rhyolite, and vulcanite. In

| Table 3. Section of projectile points by raw material and biogeographic unit: Cc cryptocrystalline rocks; Obs obsidian; Bas basalt; MNPP minimal number of PP. |
Projectile point variability from a biogeographical approach in northwestern Patagonia, Argentina

In the three biogeographic units the non-stemmed PP morphology predominates. In Altoandina, non-stemmed PP are made of obsidian and basalt, with a lower average size than in Patagonia and Monte. In Patagonia the non-stemmed PP also predominates. However, in sharp contrast, Patagonia has a higher proportion of stemmed PP (51%). Hunter-gatherers used obsidian and cryptocrystalline rocks to make both morphologies, and the size and weight of the PP are roughly the same in Altoandina and Monte. Despite the small sample size in Monte, we can observe some non-stemmed PP made of cryptocrystalline rocks and other raw materials, and very few stemmed PP.

Humberto Antonio Lagiglia (1974) and Mariano Gambier (1980) observed this spatial difference for the Early Holocene in the PP morphology: non-stemmed PP in Altoandina, and the coexistence of stemmed and non-stemmed PP in Patagonia and Monte (Figs. 2 and 4). In this paper, we observed the same pattern for the Late Holocene. This corresponds to standardized hunting practices in Altoandina, which require a specific weapon, such as the bow and arrow. In contrast, in Monte and Patagonia various hunting strategies would lead to the production and use of both hafting techniques.

The presence of non-stemmed PP in Altoandina, made of obsidian, is probably related to the bow and arrow weapon system associated with individual hunting or small hunting groups chasing prey of various sizes. This high frequency of obsidian non-stemmed PP may also be related to the discarding of entire pieces and replacement in quarry areas, or other spaces different from the occupation sites, given the low replacement index (Amick 1996). The tips and tip-mesial

Fig. 3. a Percentages of raw materials and fracture state of projectile points by geographic unit. b Weight in grams of projectile points.
fragments in Altoandina may be due to the fact that they entered the sites with the prey after the animals had been processed, suggesting that the PP were not lost on killing grounds. The low number of basal fragments may indicate the difficulty of recovering hafts on steep terrain and the related difficult access, and thus the PP were not discarded at residential camps (sensu Amick 1996).

We observe a different situation in Patagonia and Monte, where there are both weapons systems (bow and arrow, and darts). In these areas, there was more emphasis on collective hunting, with ambush hunting for big game prey in open areas. This led to a higher replacement rate on certain sites, especially in Monte. The higher discard and replacement index of PP on Monte may also be related to the quality of cryptocrystalline rocks, and to the topographic characteristics of the plains, which could require collective hunting.

Carlos A. Aschero and Jorge G. Martínez (2001) considered topographic resources as important for hunting strategies. In Altoandina, the steep slope of the terrain could facilitate the ambush of the fauna toward areas of confinement with the use of a bow and arrow. In contrast, Patagonia and Monte demand other techniques and strategies with the participation of a higher number of hunters, which would minimize the possibility of losing prey (Ratto 1993).

In the context of Argentinean Patagonia, Juan Bautista Belardi et al. (2021) proposed that different ambush tactics may have involved individual and collective hunting events, which could reflect the complementary seasonal use of terrain at different altitudes. In southern Mendoza, we observe a similar pattern related to the annual seasonal round, prey availability, weapons systems used for hunting, and the construction of stone structures, such as parapets. Patagonia and Monte could have been used intensively across the year, with access to a broader range of prey. In Altoandina, the seasonal availability of the area and a higher focus on guanaco

<table>
<thead>
<tr>
<th>ALTOANDINO</th>
<th>Raw Material</th>
<th>n</th>
<th>Length mm</th>
<th>Width mm</th>
<th>Thickness mm</th>
<th>Volumen mm³</th>
<th>Weight gr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cryptocrystalline</td>
<td>10</td>
<td>30.9, 19.9</td>
<td>6.1</td>
<td>37.51</td>
<td>3.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Basalt</td>
<td>9</td>
<td>31.4, 19.8</td>
<td>5.8</td>
<td>36.06</td>
<td>4.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Obsidian</td>
<td>11</td>
<td>21.9, 13.7</td>
<td>3.8</td>
<td>11.40</td>
<td>1</td>
<td></td>
<td></td>
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<tr>
<td>Total</td>
<td>30</td>
<td>27.7, 17.6</td>
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**Tab. 4. Projectile points metric variables by raw material and biogeographic unit.**

**Fig. 4. Frequencies of stemmed and non-stemmed projectile points in the biogeographic units.**
Projectile point variability from a biogeographical approach in northwestern Patagonia, Argentina

of southern Mendoza. In Patagonia and Monte during the FLH, there is evidence of the use of both hunting practices, bow and arrow, and darts with the atlatl. These findings must be considered preliminary, but do suggest the use of both weapons systems during the Late Holocene. The choice of system relates to prey size, the topographic characteristics of the environment, and the hunting strategies used by human groups (Martínez 2007).

Guillermo Heider and Diego Rivero (2018) mentioned that for the central pampean area of Argentina, the use of both stemmed and non-stemmed PP is related to functional requirements, which would vary according to the open or narrow locations in the landscape. Their results show that the morphological variations in PP are not related to different weapons systems.

Conclusions and future directions

This work constitutes a starting point to integrating the lithic record in the focal areas, and particularly the projectile points registered in each biogeographic unit. In future works we aim to integrate a more significant number of sites and incorporate other temporal variables that would help us understand changes and continuities in the identified trends.

Finally, Gustavo Neme, and Adolfo F. Gil (2008) proposed that the occupation of marginal environments, such as Altoandina and Monte, was due to a demographic increase, or when the technology necessary to secure subsistence in such areas was available. The coexistence of stemmed and non-stemmed PP in Patagonia, and non-stemmed PP in Altoandina, could indicate that the technological innovation of the bow and arrow made the effective occupation of such environments successful.

We observed small differences in PP weight between Altoandina and Monte, but a much higher weight in Patagonia. Obsidian PP present the lower values for length, width, and thickness, while basalt PP present the higher values. This may imply specific raw material selection for each weapon or hunting strategy. A similar pattern occurs at lower latitudes of Argentinean Patagonia, where stemmed obsidian PP are smaller and more homogeneous in their dimensions compared to PP made of cryptocrystalline rocks (Belliardi et al. 2005; Cassiodoro et al. 2020). In contrast, non-stemmed PP show more variability in their sizes.

In the temporal exploration of the sample from the Atuel valley, we found that PP were mostly made of obsidian during the ILH and FLH, followed by cryptocrystalline rocks. In the exploratory analysis of metric differences between arrows and darts, we found differences in comparison to the results of Silvina Celeste Castro et al. (2018) for northwest San Juan and central Mendoza. These earlier authors suggested that the bow and arrow replaced the weapons systems based on darts and spears in the Late Holocene due to the diffusion of this cultural trait from north to south (Castro et al. 2018). Our results indicate the coexistence of both systems during the Late Holocene at specific locations (Otaola et al. 2019) challenged hunter-gatherers to use more reliable PP (Bleed 1986). Here it is notable that Ratto (2003) suggested the bow and arrow is a more flexible technology that allows both individual and collective hunting. At the same time, hunter-gatherers used it for large and small prey, with a size range between 23 to 230kg.

Finally, Gustavo Neme, and Adolfo F. Gil (2008) proposed that the occupation of marginal environments, such as Altoandina and Monte, was due to a demographic increase, or when the technology necessary to secure subsistence in such areas was available. The coexistence of stemmed and non-stemmed PP in Patagonia, and non-stemmed PP in Altoandina, could indicate that the technological innovation of the bow and arrow made the effective occupation of such environments successful.

**Conclusions and future directions**

This work constitutes a starting point to integrating the lithic record in the focal areas, and particularly the projectile points registered in each biogeographic unit. In future works we aim to integrate a more significant number of sites and incorporate other temporal variables that would help us understand changes and continuities in the identified trends.

In the future, it would be helpful to explore elements associated with strategies and hunting techniques in open-air sites in southern Mendoza. We also need to integrate information from the identification of para-pets, sighting places, interception, and ambush locations of prey, linked to the information available on butchering sites and changes in the size of prey.
Acknowledgements

We are grateful to Gustavo Neme and Adolfo Gil for their consistent support and insights in the research of deserts and high-altitude landscapes through a biogeographic approach. To our colleagues from IDEVEA and our families for their unconditional encouragement. To CONICET and the National Agency of promotion of Science and Technological Development for financing our research (PICT 2019-04447 and PICT 2020-2053).

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