Land-use and ceramics in the Andean highlands of Patagonia, Argentina

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ABSTRACT - The aim of this paper is to study the use of ceramics of small-scale societies during the late Holocene in northern Patagonia. The technological investment model predicts that use-time and utility will determine the investment spent in ceramics. We explore how ceramics were used in short-term camps and aggregation sites during summer at high elevations, and residential camps during winter at lower elevations. To test the investment in ceramics we use four technological variables: temper size, average thickness, surface treatment and firing. Our results indicate that hunter-gatherers expected a short-term use in summer locations and therefore made a low investment in ceramics.

KEY WORDS - ceramic analysis; use of space; northwestern Patagonia; hunter-gatherers

Introduction

In mobile societies, the use of ceramics may be problematic if the manufacturing process interferes with residential movements and the acquisition of seasonal resources, such as when the vessel drying and firing process requires foragers to stay in places for longer periods. Yet the potential benefits of ceramics to the subsistence system may include improved return rates on seed crops and animal products, like bone, if cooking releases more calories relative to the time invested in their acquisition (Bettinger et al. 2006; Sturm et al. 2016). In this paper, we explore the following research question: How was ceramic technology used by small-scale mobile societies in the highlands of northwestern Patagonia?
Hunter-gatherers face many constraints when considering the use of ceramic technology: (1) the utility and costs of similar technologies such as basketry and leather bags; (2) the fragility of the pots and whether or not they can be moved between residential and/or logistical camps; (3) scheduling conflicts between ceramic production and other activities such as seed gathering; (4) the small scale production does not take advantage of the opportunity to fire large amounts of pots in a single event (Eerkens 2003; 2008); and (5) the time needed to stay in a location and form, dry and fire a pot (Arnold 1985).

There are different strategies with regard to the use of ceramics among small-scale mobile societies: caching them at specific locations instead of moving them as the seasons change (Eerkens 2008), producing expedient pots for a single use and then discarding them (Gibbs 2012), and trading with nearby neighbours (Beck 2009). In addition to learning why and when this technology was acquired, we can explore how hunter-gatherers managed the costs of producing and transporting this technology in light of their seasonal constraints, movements, and needs. Variation in ceramic use across settlement systems permits investigation of patterns of mobility and seasonality. To interpret such variation, we need to consider the differences among the ecological zones and their limitations, the energy spent on manufacturing them, the utility of the vessels, and the duration of their use.

Our objective is to investigate how hunter-gatherers from northwestern Patagonia complemented the use of land to mitigate risk with ceramic technology in the context of aridity and high elevation environments. Through the study of settlement patterns and the use of ceramics we determine how different strategies permitted the adaptation to different ecological zones, and especially the highlands.

Ceramics and land-use in mobile small-scale societies

There is a high correlation between ceramic technology and sedentism (Arnold 1985), mainly related to the different steps of the manufacturing sequence, which involves raw material acquisition, modelling, drying and firing. In 85% of the reported ethnographic cases, clays come from a radius within 1–5km (Arnold 1985). While vessel modelling can be a relatively fast activity, drying is often a step that does not take much effort but requires staying in one place until the process is complete, which can take days or weeks, depending on humidity and temperature. Moreover, firing is a step in which the whole process is at stake – it can go well and finish with a good production rate, or it can go wrong and be a great loss. Therefore potters often keep their firing know-how secret, with many myths surrounding the activity to ensure more security for the manufacturer (Rice 1999). Furthermore, since the firing stage is so important having an economy of scale is an advantage, and it pays off to produce a considerable number of pieces, such as more than 25 (Eerkens et al. 2002).

We use the technological investment model (TIM) to explore how ceramics were used in the Diamante Valley (Fig. 1). The core concepts of the model derive from the Marginal Value Theorem (Charnov 1976). Andrew Ugan, Jason Bright, and Alan Rogers (2003) noted that the model considers different technologies along the same utility curve, which makes it difficult to compare variants of different categories, for example a porcelain teapot versus a Stanley thermos to keep water hot. Robert L. Bettinger, Bruce Winterhalder, and Richard McElreath (2006) thus improved the model by segregating each technological variant with its own utility curve, permitting independent comparisons for variants within the same technology (low or high investment ceramics), and variants of different technologies with the same function – e.g., the use of leather bags, basketry, and ceramics.

For example, we can consider the use of baskets and ceramics as options for cooking or containers. The TIM application developed by Camilla Sturm, Julia K. Clark, and Loukas Barton (2016) allows us to identify the role of utility as a variable that may affect the adoption of ceramics. Specifically, direct-heat cooking provides greater returns because it requires less fuel and labour, facilitating the detoxification of certain plant products, degreasing bones, and processing small seeds that need long, slow cooking (Sturm et al. 2016). These advantages solve scheduling problems related to subsistence practices, labour scarcity, and wood shortages. In addition, ceramics can be produced at scale more easily than baskets, and among hunter-gatherers this can be during an aggregation scenario. For the context of northwestern Patagonia, this is what we would expect for the high-elevation villages. In these locations wild plants are scarce, and therefore it is possible hunter gatherers brought domesticated plants with them to complement their diet, and ceramics may have helped with the storage and cooking of these. Moreover, cooking in pots may have boosted...
the calorific returns of the guanaco and bird meat available nearby. Despite a higher demand and scale in the highland villages, there is also a severe lack of wood, and therefore is very unlikely that ceramic production and firing occurred at such locations. The use of pots may also have helped to make more efficient use of wood in cooking. Finally, Sturm et al. (2016) explain that in a longer expected use-time scenario it would be more worthwhile to invest in ceramics.

According to Sturm et al. (2016), the core concept of the TIM is that the amount of time one would invest in a certain technology will depend on the expected use-time and the utility or benefits that can be obtained from it. Therefore, more expensive technologies that provide higher returns will replace cheaper and less beneficial technologies when their use-time outweighs the production cost.

One way to use ceramics within a high mobility culture is to produce cheap pots that can be easily discarded (Gibbs 2012). This is similar to expedient lithic technology performed on local raw materials. In contrast, curated pots with multiple functions might be suitable to transport among sites, allowing reliable and frequent use under an uncertain and patchy environment (Sturm et al. 2016). In the context of northwestern Patagonia, we would expect to find low-investment ceramics used during summer in the highlands. These pots would be made with local clays and temper, mostly unsorted sands, and fired at low temperatures (c. 650°C) with uneven firing, represented by oxidized, incomplete firing. Conversely, we would expect to find high investment ceramics used during the rest of the year in the piedmont and the lowlands. These pots would be made with a preferred clay and prepared temper, designed to reduce thermal and physical stress, fired carefully to increase the pot strength, and with surface treatment designed to boost efficiency.

In the Diamante Valley we observe that ceramics were more important for subsistence activities in the intermediate valleys and the high-elevation villages (Franchetti 2019; 2022; Morgan et al. 2017; Neme 2007; 2016). The model applied to foragers who use ceramics in summer predicts low investment related to the immediate and short-term expected use. However, a smaller proportion of the ceramics in the assemblages would have required a higher investment, as related to ceramics prepared for winter and therefore tied to long-term use. In addition, in summer a low proportion of locations could also have high investment ceramics related to longer use, such as rockshelters.

**The Diamante Valley: archaeology and environment**

Archaeological research over the past 20 years suggests that late Holocene people of northwestern Patagonia did not cultivate domestic crops, in spite of their proximity to farmers, but instead subsisted on wild camelids such as guanacos (*Lama guanicoe*), large flightless birds, small game, and seeds (Otaola et al. 2019; 2023). Around 2000 years ago, demographic pressures, perhaps the result of human population growth, may have forced more intensive resource procurement and processing behaviours, as well as more regular and extensive interactions between individuals and groups over large areas (Otaola et al. 2023). Gustavo Neme (2007) describes an intensification process that provoked a series of social changes, including the incorporation of new technologies, such as ceramics and the bow, and the increase of exchanges and territoriality.

The data available from other areas of northwestern Patagonia (Sugrañes 2017a) indicates that ceramic technology played an important role in the subsistence system, without implying an important role in ritual activities. In fact, the forms studied from museum collections of the area reflect a wide variety of potential functions: pots, jars, bowls, vessels and cups (Sugrañes 2017b). This functional variability reflects the greater importance of pots linked to cooking and storage – reinforcing the idea that the technology is organized around subsistence and service. From reported radiocarbon dates associated with ceramics in sites of the Diamante Valley we can establish that ceramics were incorporated into the ways of life there around 2300 years BP (Lagiglia 1997). Furthermore, there is a higher frequency of radiocarbon dates associated with ceramics, indicating a more consistent occurrence between 1500 years BP until 500 years BP. It is plausible that beyond the earlier dates ceramics were more often used 1500 years BP, when the presence of different ceramic styles increased (Morgan et al. 2017; Sugrañes, Franchetti 2012).

In northwestern Patagonia, resource productivity and distribution varies in space owing to the enormous variability in average annual rainfall, topography, elevation, and the distribution of different soils across
different ecological zones. Resources are therefore heterogeneously distributed and seasonally available. Average annual rainfall in the deserts of northwestern Patagonia is 250mm. Humans inhabit elevations from 700m above sea level in the lowlands to 3600m in the highlands (Franchetti 2019). Water is abundant in the highlands during the summer but scarce in the lowlands. While plants are more abundant in the lowlands, large animals are more abundant in the piedmont, though they move seasonally to the highlands in summer and to the lowlands in winter (Fig. 1).

The rockshelter sites are at an altitude between 2000 and 2300 masl. There are two sites excavated by Gambier in the 1970s, Alero Montiel and El Mallín, dated 1500 years BP (Giardina et al. 2017), and one test pit excavated in Cave Manantial. The survey sample consists of ceramics from surface base camps in the highlands (altitude between 2000 and 3000 masl) and one surface base camp in the piedmont (altitude at 1600 masl) (Franchetti 2019).

During the last two decades, systematic excavations have been conducted at three high elevation sites with stone structures: El Indígeno, Laguna el Diamante, and Risco de los Indios. These sites date to the Late Holocene, and all of them share certain characteristics: (1) they are located between 2400 and 3400 masl, next to water courses and areas rich in flora and faunal resources called ‘vegas’; (2) they are close to mountain passes and contain stone structures; (3) they were occupied within the last 2000 years BP and the people who lived there had a focus on camelid hunting with the complementary use of wild and domesticated plants; and finally (4), they all contain obsidian and ceramics from both sides of the Andes (Dunin et al. 2006; Lagiglia 1997; Morgan et al. 2017).

On the basis of more than 200 stone structures, El Indígeno has been described as a summer occupation site linked to a pattern of vertical transhumance. Further evidence of this includes goods from both sides of the Andes: ceramics, shells, domesticated plants (maize), high proportions of guanacos and birds (Franchetti 2019). The importance of ceramics at El Indígeno is evident from the results of an index showing the amount of ceramics divided by the sum of other archaeological materials, with the highest ratio for the region (Neme 2007). In addition, some pots were found upside down and this was interpreted as a cache strategy for the reoccupation of the site (Lagiglia 1997). Neme (2016) argues that the structures were
not occupied simultaneously, and some of the newest structures were built with rocks from the older ones. Guanacos were the main food resource consumed, supplemented with processed plants as suggested by the remains of both maize and grinding stones. Some remains that belong to the lowlands – such as *Zea mays*, *Lagenaria sp.*, *Emepetrum sp.*, obsidian, silica, steatite, pottery, and mollusc shells – suggest the intention to minimize risk at high altitude. The amount and diversity of goods from both sides of the Andes have been interpreted as indicative of exchanges between communities from Chile and Argentina (Neme 2016).

Risco de Los Indios consists of 29 structures that are mainly circular or ovoid. The archaeological record presents local plants, animals, and lithic raw materials, although the obsidian, ceramics and *Phaseolus sp.* that have been found come from the lowlands or even as far away as Chile (Morgan et al. 2017). The main difference between Risco de Los Indios and both El Indígeno and Laguna del Diamante is that it has fewer structures and was occupied later. Morgan et al. (2017) suggest that the use of high elevation villages began about 2100 years ago, peaked between 1500 and 600 years ago, and the population then shifted or moved to slightly lower altitudes thereafter.

**Methodology**

To test different degrees of investment across the high-altitude landscape of the Diamante Valley we compare four assemblages: (1) Surface survey (N=152), with locations between 1400–2600 masl; (2) Rockshelters (N=170), located between 2000–2300 masl; (3) Risco de los Indios (N=284), a highland village located at 2500 masl; and (4) El Indígeno (N=668), the largest highland village known at the time, located at 3400 masl.

Ceramic materials were cleaned and then subjected to low-power microscopic analysis with a binocular Nikon SMZ stereomicroscope 800 with an objective magnification of 1x and 10x (Fig. 2). We measured the maximum temper size in mm and the temper size in the categories Fine, Medium, and Large (Orton et al. 1993). In the study area we consider local sands as inclusions, and we have detected several common minerals such as quartz, feldspar, and amphibole, among others. In contrast to other areas, we have not identified shells, fibers or grounded ceramics reused as inclusions. It is highly probable that some of the listed minerals are also mixed in with the clays. However, we interpret the proportions seen in the paste as intentionally added (Fig. 2).

Ceramic sherds were also analysed macroscopically and measured in mm with regard to width, length, and thickness. Different categories were recorded for surface treatment (polished, burnished, smoothed), decoration (painted, incised), and firing (oxidized, oxidized incomplete, reduced) (Orton et al. 1993; Simms et al. 1997).

To explore the degree of investment in ceramic production we will focus on four variables based on the following assumptions (Eerkens 2003; 2008; Roux 2019; Simms et al. 1997): a finer wall thickness demands more work as the piece gets more fragile and unstable during manufacture; a finer and more homogenous temper size implies some extra work in the selection of temper before it is added to the clay; reduced firing implies special techniques and care to reduce the oxygen in the atmosphere during the process; and smoothing is the most common surface treatment (Rice 2015; Simms et al. 1997), as opposed to brushing and polishing. Vessel thickness, temper size, firing and surface treatment should show low investment for the sites of summer aggregation in the highlands, and high investment for the sites in the piedmont. Table 1 presents the degree of investment expected for different
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Then the rockshelters, the survey assemblage, and finally Risco de los Indios.

In Figure 4.A the black line that crosses the bullet graphs from the proportion value indicates that the differences in fine temper size proportions are significant for rockshelters and El Indígeno at 80% confidence level. In Figure 4.B the black line that crosses the bullet graphs from the proportion value shows that the differences in smoothed surface treatment proportions are significant for all the assemblages at 80% confidence level. In Figure 4.C the black line that crosses the bullet graphs from the proportion value indicates that the differences in reduced firing proportions are significant for rockshelters and Risco de los Indios at a 99% confidence level.

From these ceramic results, and beyond some variability among the assemblages, we observe a general pattern which consists of the following: average thickness suggests a low level of investment between 5 and 7mm; temper size percentages are mostly medium between 40–70%; firing technique is mostly oxidized, except for a 40% of reduced firing in the rockshelter assemblage; and the surface treatment is mostly smoothed with ranges of 60–90%. Overall, these assemblages for the Diamante Valley ceramics indicate a trend toward low investment.

We grouped the findings of ceramics from a surface survey (N=152) and compared them to three other samples. We grouped the ceramics from the sites El Mallín and Alero Montiel, excavated by Gambier in the 1970s, together with a sample from Manantial cave, in the sample called rockshelters (N=170). Another sample includes the ceramic materials from an excavation at Risco de los Indios (N=284) (Sugrañes 2016), one of the high elevation villages previously described. The fourth sample are the surface collections materials from El Indígeno (N=668) (Franchetti, Sugrañes 2012).

The survey assemblage has an average thickness of 6.3±0.33mm; the rockshelter assemblage has an average thickness of 5.8±0.17mm; the Risco de los Indios assemblage has an average thickness of 6.8±0.19mm; and the El Indígeno assemblage has an average thickness of 5.4±0.13mm; all at a 95% confidence level. Figure 3 indicates that these assemblages are significantly different (at a 95% confidence level) with regard to the average thickness, evidencing an increasing investment for this variable from El Indígeno, then the rockshelters, the survey assemblage, and finally Risco de los Indios.

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<table>
<thead>
<tr>
<th>Degree of investment</th>
<th>Thickness</th>
<th>Temper Size</th>
<th>Surface Treatment</th>
<th>Firing</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Investment</td>
<td>5mm</td>
<td>Fine (0-0.2mm)</td>
<td>Polishing</td>
<td>Reduced</td>
</tr>
<tr>
<td>Moderate Investment</td>
<td>6mm</td>
<td>Medium (0.2-0.5mm)</td>
<td>Brushing</td>
<td>Oxidized incomplete</td>
</tr>
<tr>
<td>Low Investment</td>
<td>7mm</td>
<td>Large (+0.5mm)</td>
<td>Smoothing</td>
<td>Oxidized</td>
</tr>
</tbody>
</table>

Tab. 1. Degree of investment associated with different states of the variables.

<table>
<thead>
<tr>
<th>States of the variables</th>
<th>Thickness</th>
<th>Temper Size</th>
<th>Surface Treatment</th>
<th>Firing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness</td>
<td>ER</td>
<td>Percentage</td>
<td>ER</td>
<td>Percentage</td>
</tr>
<tr>
<td>Fine (0-0.2mm)</td>
<td>6.9</td>
<td>26.3</td>
<td>17.6</td>
<td>25.5</td>
</tr>
<tr>
<td>Medium (0.2-0.5mm)</td>
<td>7.6</td>
<td>59.2</td>
<td>62.9</td>
<td>47.4</td>
</tr>
<tr>
<td>Large (+0.5mm)</td>
<td>5.3</td>
<td>13.2</td>
<td>14.7</td>
<td>27.1</td>
</tr>
</tbody>
</table>

Tab. 2. Percentages and error ranges (ER) at a 95% confidence level for temper size, surface treatment and firing among the assemblages from the Diamante Valley.
Discussion

Our research question was as follows: How was ceramic technology used by small-scale mobile societies in the highlands of northwestern Patagonia? We can answer that ceramics are more abundant in the highlands, and their use is also present and more important in high-elevation villages and some rockshelters. The investment in ceramic technology, beyond some internal variability, is low.

This is consistent with the idea proposed by Sturm et al. (2016) that when hunter-gatherers stay in summer camps they will tend to invest less in this technology because they do not expect to use it for very long, and there is a conflict with other activities important to subsistence during this season. This contrasts sharply with previous expectations that related the higher investment in ceramics with increasing altitude (Franchetti, Sugrañes 2012). The application of the TIM model undermines the use of environmental determinism when we try to explain human decisions to adapt to marginal conditions. Even in those contexts, small-scale societies prove to have a myriad of strategies to manage risk and contingency.

Hunter-gatherers of the Diamante Valley made decisions on how to incorporate ceramics considering the use-time at certain locations while evaluating the manufacturing time and the utility to be gained. Jelmer W. Eerkens (2003) suggests that a strategy hunter-gatherers use to engage in ceramic technology is through the re-occupation of settlements. By caching pots in the summer settlements in the highlands people reduce the cost of transport and increase the expected use-time. However, the low investment observed in the variables of thickness, temper size, surface treatment and firing suggest that human groups did not expect to use the pots for very long. This is consistent with the availability of the highlands and use of the highland villages only during summer. This could also suggest that there was not a reoccupation of these locations each year. This may imply that different locations were occupied across generations in the Perdido stream, although the re-occupation of these sites may not have been the norm. This secondary tributary of the
Diamante River was probably a pass through which people moved towards higher elevation patches and the high-elevation villages.

The discussion of trade or local production would require further exploration, but we can set a basic framework. It is very likely that ceramics were produced locally as is evidenced by the predominance of local styles in the Diamante Valley. The presence of other styles, even in very small frequencies, suggests that they were acquired through exchange or even visits from groups who spent the other months of the year living on the west side of the mountains. The exchange of gifts might have reinforced alliances that allowed the use of complementary regions and access to other territories when the groups from one or the other were under nutritional stress. A similar pattern has been proposed for southern Mendoza, with the high-altitude villages serving as aggregation areas for groups from different ecological regions (Lagiglia 1997; Neme 2007). In summary, ceramics were more prevalent in the highlands although investment in their production was low, as might be expected for summer camps in mobile societies, for which the expected use-time was low.

Hunter-gatherers face many challenges when incorporating ceramic technology. Mobility, the main strategy for buffering the heterogeneous distribution of resources both in time and space, implies serious constraints on the accumulation of goods. Ceramic technology competes with previous technologies such as basketry and leather manufacturing, which can be lighter and less fragile in transport (Eerkens 2003; 2008). However, when hunter-gatherers rely more on upland areas within their seasonal mobility range, the importance of new technologies such as ceramics played a key role in boosting the occupation of more risky environments (Barton 2016).

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