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RESEARCH REPORT

Human Dispersal in the Atlantic Slope of Patagonia and the Role of Lithic Availability

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ABSTRACT
The purpose of this paper is to understand the role of different resources in the human ranking of habitats during the peopling of the Atlantic slope of Central-South Patagonia, as well as the technological strategies used during early human dispersal. We studied the distribution of early sites in the Deseado Massif, where there is a relatively high concentration of evidence of early human activity. We analyzed published information related to site chronology and distribution, presence/absence of hearths, raw-material provenance, the presence of bifacial artifacts and reduction activities, the location of corridors, and least-cost paths among sites. Results show that water would have been the most important resource in selecting locations. The availability of high-quality rocks would have been an asset, which also helped to generate a highly visible archaeological record in which bifaces were important. These resources were probably exploited using a multidirectional half-radius pattern of movements, basically restricted to the eastern margin of Massif.

KEYWORDS
Patagonia; initial human dispersal; lithic resources

1. Introduction

According to current knowledge, the process of peopling of Patagonia was one of a slow fill-in of empty spaces (Borrero 1989–90, 1994–95). The model contemplates the human exploration of new lands, sometimes followed by colonization. The known early sites in the Atlantic slope, which are a result of this process, are not evenly distributed in the space. Although research biases and formation processes can be at least partially responsible for this distribution, it is also true that hunter-gatherers rarely make use of the whole geographical space with the same intensity (Borrero 1989–90). For that reason, the archaeological evidence for the exploration of some places could be relatively late in comparison to that from the older sites of the region. Early human populations probably used different strategies for dispersal into new land, with water probably having an important role in these low precipitation environments (e.g., Pérez et al. 2016; Veth 2005). Eastern Patagonia has very few annual repositories of drinking water between the river basins (Borrero 2005; Mayr et al. 2005; Miotti and Salemme 2004); accordingly rivers could have had an important role during these initial movements.

Exploration refers to the initial radiation of humans to new empty land. We think that during initial exploration humans probably moved along natural routes, and that non-optimal localities were used. According to Borrero (1989–90), a low density of sites can be expected, as well as low occupation redundancy, leading to low expectations for the recovery of relevant archaeological sites (Borrero 1989, 1994–95). A more recurrent use of sites located in optimal locations is expected during land colonization, which is the phase of settling-in, when a region begins to be fully used and a relatively good knowledge of the distribution of resources and associated ecological cycles exists, as well as clusters of sites with good visibility and stratigraphic resolution (Borrero 1989–90, 1994–95).

There are many possible reasons for exploration and eventual colonization of a region, including among others the gradual extension of hunting ranges, the fission of bands, or the search for high-quality raw-material sources (Anderson and Gillam 2000). The speed of this dispersal is probably related to the degree of environmental homogeneity between the previously known areas and the new lands (i.e., Kelly 2003a). Most of the evidence for this process can be elusive, especially taking into account the low human demography expected for that time, the difficulty of finding early open-air occupations, and the formation processes involved.

During the early exploration and colonization of Patagonia, environmental conditions were different from

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those existing today. By ca. 16,000 cal yr BP, the retreat of the Andean glaciers was taking place (Glasser et al. 2012). Human southern expansion probably took place at a time when the Atlantic coast extended several km to the east, increasing continental conditions (Ponce, Borromei, and Rabassa 2011). At this time, the Antarctic Cold Reversal (ACR), which lasted from 14,500 to 12,700 cal yr BP (Blunier et al. 1997; Moreno et al. 2012), was taking place, followed by the Younger Dryas (YD), which in the Southern Hemisphere was a warmer period that lasted from 12,700 to 11,500 cal yr BP. A maximum postglacial temperature was reached around 11,500 cal yr BP (Bianchi and Gersonde 2004). The river basins were probably established by that time (McCulloch et al. 1997).

It was recently proposed that the human presence in the Pacific slope of South America at ca. 42° S started at least sometime near 18,000 cal yr BP (Dillehay et al. 2015). However, most of the replicated dates in the Atlantic slope are not earlier than 13,000 cal yr BP (e.g., Brook et al. 2015; Franco et al. 2010; Miotti, Salemme, and Rabassa 2003; Paunero 2000; Paunero et al. 2007; Steele and Politis 2009). Since this chronological signal is recorded at several places in Patagonia, it appears safe to say that it is the time when the process of colonization was consolidated in many Patagonian regions. Accordingly, older dates can be expected for the first human entries to those regions.

The purpose of this paper is to investigate the role of different resources, including lithics, in the human ranking of habitats during the peopling of the Atlantic slope of Central-South Patagonia, as well as the technological lithic strategies used during initial human colonization. This process involved different kinds of environments, with humans probably using least-cost paths and settling in rich resource areas.

2. The study area

Patagonia is composed of a series of progressively lower plateaus extending eastward from the Andes (Soriano 1983), which are crossed by rivers that flow with a general West–East direction from the Andes to the Atlantic Ocean. The climate is arid to semi-arid, with mean annual temperatures that range between 12 and 3°C (Paruelo et al. 1998; Soriano 1983). There is a very steep gradient of mean annual precipitation resulting from the presence of the Andes. It decreases towards the east, from around 1000 mm in the Andes foothills to less than 200 mm in the central plateau (Soriano 1983). A deciduous forest of *Nothofagus antarctica* and *Nothofagus pumilio* is present along the eastern slopes of the Andes, while Extra-Andean Patagonia is an area dominated by semi-arid grass and shrub steppes, with dwarf-shrub communities in the drier areas of the central plateau, adapted to cope with severe water deficits (León et al. 1998; Roig 1998).

The Deseado Massif, where our analysis is centered, is a morphostructural region shaped by volcanic activity during the Jurassic (De Giusto, Di Persia, and Pezzi 1980). The Deseado Massif is variable in geology, geomorphology and spatial and temporal availability of water. However, it has an important characteristic, which is the availability of high-quality siliceous rocks, as has been recognized by different researchers (Cattaneo 2000, 2004; Franco et al. 2015; Hermo 2008; Skarbun 2009). Those rocks can be obtained from the Chon Aike, La Matilde, Bajo Grande, and Baqueró formations, as well as from siliceous infills (e.g., Echeveste 2005; Panza and Haller 2002; Panza and Marin 1998; Zubia 1998). The process of silicification is more important in the north than in the south of the Massif. Pampa del Asador, located west of the Massif, is the most important source of black obsidian (Stern 2000). Other secondary sources have been located toward the east, one of them more than 170 km away, at only 10 km south of the Deseado Massif (Franco et al. 2017). More recently, Nami and coauthors, on the basis of the presence of isolated pebbles of obsidian along the coast, have suggested the possibility that obsidian nodules from Pampa del Asador were transported and deposited among the Patagonian gravels (Nami et al. 2018). However, this must be analyzed in further detail since they have not been reported for the Deseado Massif and nearby locations. Some of the samples reported by Nami and coauthors were obtained at archaeological sites (Punta Medanosa), and only very general information was offered for the provenience of the rest of the samples.

3. Methodology

For the purpose of this paper, we studied the distribution of early sites in the Atlantic slope of Patagonia. Due to the relatively high concentration of sites in the Deseado Massif, we analyzed published information generated by different research teams related to site chronology[1], distribution, discard rates, presence/absence of hearths, raw-material provenance, presence of bifacial reduction activities, the location of corridors between cores, and least-cost paths among sites. As some of the sites are still being excavated, information about the excavated area at each site was included.

We consider that the presence and size of the hearths provide clues about the length of the human stay, especially if there was no cleaning of the hearths, and the sites were not continuously occupied, as it seems to have been the case (e.g., Brook et al. 2015; Franco et al. 2010; Paunero et al. 2007). The utilization of bifaces as part of a curated strategy for peopling of new environments has been suggested, not only in North America but also in South America (Borrero and Franco 1997; Franco 2004, 2012; Kelly 1988; Meltzer 2009; Waters and Jennings 2011). During the colonization of new environments, the presence of bifaces can be related to the possibility of using them for different tasks and/or as cores for producing large and usable flakes (Kelly 1988), as well as to solve environmental incongruencies (Meltzer 2009). During the human colonization of spaces, a better knowledge of the local resources in comparison to the times of initial exploration can be expected. In addition, a less intense use of immediately available rocks can be expected, except when high-quality rocks are involved (Borrero and Franco 1997; Franco 2012). Rock sources available in highly specific places are now expected to be used, increasing the percentage of locally available high-quality rocks, and creating a better relationship between the task at hand and the rock characteristics.

In the case of the Deseado Massif, there are different definitions of local rocks. For example, Skarbun et al. (2007) consider as local only rocks that can be obtained at distances of less than 20 km, while those obtained beyond that distance are considered exotic. In addition, rocks which can be obtained within the same landscape unit (Skarbun et al. 2007) where the site is located, are considered as immediately available. On the other hand, following Meltzer (1989) and relevant ethnographic data, Franco (2004) considers rocks obtained up to distances of 40 km as local, dividing them between those that can be obtained up to distances of 10 km (close local) and those that are more distant (distant local) (Civalero and Franco 2003). The concept of immediate vicinity, originally developed by Goodyear (1989), is also used by these authors, who differentiate these rocks from those available at greater distances.

From a biogeographical perspective, GIS was used to model the landscape on the basis of actualistic information and as a tool to analyze connectivity between cores and archaeological sites. Humans move and make decisions along the landscape where they are settled (e.g., Bird and ÓConnell 2006; Foley 1981). Modeling of human routes using GIS – based on topography – has been applied in different South American environments (e.g., Barberena et al. 2017; Cortegoso et al. 2016; Lucero, Marsh, and Castro 2014; Miotti and Magnin 2012; Rademaker, Reid, and Bromley 2012; Tripcevich 2008).

The concept of distance is basic to the understanding of spatial relationships. Movements in landscape imply a variable cost expressed in distance, time, or energy. Raster layers that contain a cost variable are called friction surface. In this study, the spatial analyses are based on making an anisotropic cost surface from the ArcGIS Path Distance function. The anisotropic cost relates energy consumed with the degree of slope, taking into account that energy wasted varies according to the degree of slope, in an irregular and non-constant way (Conolly and Lake 2009; López Romero 2005).

Taking into account the ecological basis of Borrero's model for the human peopling of Patagonia (Borrero 2011), we selected ecological cores in the steppe and forest, arbitrarily located in places with water availability, e.g., close to rivers. This makes sense in terms of the known history of human occupation of Patagonia (Pérez et al. 2016) and also derives from considering water a critical resource.

With reference to water, cores were set up close to rivers, in the Southeast of the Deseado Massif, and close to the western forest. In the case of the southern massif, palynological studies suggest the existence of more humid conditions during early occupations of this environment (Brook et al. 2015; Mancini, Franco, and Brook 2012). In a previous paper (Franco et al. 2018), the drainage network during wetter periods was modeled on the basis of topography, using GIS, flow direction, and accumulation analysis (e.g., Li 2014; Maidment 2002; Merwade 2012; Wheatley and Gillings 2002). This procedure suggested the existence of water availability to the southeast of the Deseado Massif, and because of this reason, a core was set up in this area.

Natural routes of less resistance and main geographic vectors related to mobility were modeled using GIS (i.e., Cortegoso et al. 2016). Natural corridors were modeled between ecological cores in places with permanent or temporal water, using *LinkageMapper* to model this connectivity among ecological cores (McRae et al. 2008; McRae and Kavanagh 2011). The location of archaeological sites was related to these corridors and also to geological formations containing high-quality siliceous rocks. In a second step, Least Cost Path analysis (LCP) was used to model connectivity among archaeological sites (i.e., Lucero, Marsh, and Castro 2014; Rademaker, Reid, and Bromley 2012), which were compared with the location of corridors. In both analyses, each cell has a resistance value related to the difficulty of moving across the cell, which is related to the topographic characteristics of the environment modeled from digital elevation models (DEM) (Tachikawa et al. 2011). Both analyses process the resistance raster and the cores map following different steps: identify adjacent (neighboring) core areas, construct a network of core areas using adjacency and distance data, and calculate costweighted distances and least-cost paths (McRae and Kavanagh 2011). The distance values between archaeological sites in the Deseado Massif, water, and lithic resources were extracted using the Euclidean Distance tool. As most of these sites and resources are located at altitudes of less than 400 masl, we consider that, in this case, distance is the most important variable. Because of this reason, isotropic analyses were carried out between sites and water resources, and between sites and geological formations with raw materials of excellent quality.

4. Results

4.1. Chronology, length of occupation, and artifact characteristics

In the Atlantic slope of Patagonia, most of the sites with dates earlier than 10,500 cal yr BP come from rockshelters and caves (e.g., Brook et al. 2015; Franco et al. 2010; Martin et al. 2015; Massone and Prieto 2004; Paunero 2000, 2003a, 2003b; Paunero et al. 2007; figure 1). These sites, some of which probably correspond to the early exploration and colonization of this space, have a highly discontinuous distribution. As can be seen in Figure 1, most of them are located in the Deseado Massif.

In this paper, we focus our analysis on the characteristics and location of sites with replicated early dates in the massif (Brook et al. 2015; Franco et al. 2010; Miotti, Salemme, and Rabassa 2003; Paunero 2000, 2003a, 2003b; Steele and Politis 2009). Although efforts have been reported to find open air sites (Franco pers. obs.; Paunero et al. 2007, 2015), all the discovered early sites are located in small rockshelters and/or caves (Figure 2). However, preforms and fragments of projectile points that can be attributed to early periods due to their technological or morphological characteristics have been found in open-air spaces, indicating the complementary utilization of these locations (Brook et al. 2015; Franco and Vetrisano forthcoming). It is worth mentioning that, even in Patagonia, there is great variability within the so-called Fishtail projectile points (e.g., Bird 1969; Castiñeira et al. 2012; Hermo and Terranova 2012; Hermo, Terranova, and Miotti 2015; Jackson 2002, 2004; Massone and Prieto 2004; Miotti, Hermo, and Terranova 2010; Nami 2003), suggesting that it probably was more than an early design used by hunter-gatherers, as was suggested for South America as a whole (e.g., Flegenheimer, Miotti, and Mazzia 2013; Franco and Vetrisano forthcoming; Hermo, Terranova, and Miotti 2015; Massone and Prieto 2004; Nami 2014; Suárez 2010). Some of the recorded variation of these early designs can be attributed to the existence of resharpening processes (e.g., Castiñeira et al. 2012; Hermo, Terranova, and Miotti 2015). The function of the miniatures identified in a few sites is unknown. Politis, Messineo, and Kaufmann (2004) have attributed them to learning activities involving kids. However, Flegenheimer and coauthors, based on their minimum in labor investment but the existence of some morphological similarities, believe they have some social significance related to hunting activities (Flegenheimer and Weitzel 2017; Flegenheimer, Weitzel, and Mazzia 2015). The dates obtained for these projectile points in Pampa and Patagonia are older than 10,200 cal yr BP (e.g., Flegenheimer, Miotti, and Mazzia 2013; Martin et al. 2015; Massone and Prieto 2004; Nami 1987). The early Holocene radiocarbon date reported for Pali-Aike cannot be used since it was made on a pooled sample of *Mylodon*, *Hippidion*, and camelid bones (Bird 1988).

Table 1 presents early sites with replicated ages earlier than 10,500 cal yr BP in the Deseado Massif. Figure 3 shows their distribution.

The earliest date obtained corresponds to Cerro Tres Tetas, cave 1 (Paunero 2000; Paunero 2003a; Steele and Politis 2009). With the exception of Piedra Museo and Cueva Túnel, there is a decrease in radiocarbon dates from North to South, suggesting a N-S general peopling direction (Table 1, Figure 3), which is in accordance with general knowledge (e.g., Borrero 1989–90, 1994–95; Miotti and Salemme 2004). According to paleoenvironmental information, by the time of the early peopling of Piedra Museo, a shrub steppe was present in the area, which changed into a grass steppe by ca. 12,800 cal yr BP (Borromei 2003). Meanwhile, to the south, in Casa del Minero, a grass steppe was present during the initial peopling of the area, with a change to a shrub steppe at ca. 12,000 cal yr BP (De Porras 2010). More to the south, early human occupations took place under more humid conditions (e.g., Brook et al. 2013, 2015; Mancini, Franco, and Brook 2012; Mancini, Franco, and Brook 2013).

There is similarity of human dates obtained at Piedra Museo, Casa del Minero, and La Gruta 1, all of them located very close to the border of the Deseado Massif (Figure 3). Fishtail or projectile points with early designs were recovered at these sites (i.e., Piedra Museo) or on the surface in nearby places (La Gruta and neighboring localities Laguna Escondida and El Engaño; cf. Vetrisano and Franco forthcoming). In the case of Piedra Museo, a deposit containing two Fishtail projectile points was dated between 11,935 and 12,436 cal yr BP (Miotti, Salemme, and Rabassa 2003).

Discard rates at these sites were calculated taking into account the quantity of artifacts and tools recovered within dated deposits, divided by the difference between

Figure 1 Distribution of sites with dates earlier than 10,500 cal yr BP in the Atlantic slope of central-south Patagonia.

the maximum and minimum mean dates obtained at the deposit where they were recovered, and then divided by the total excavated surface. In general, there are low artifact discard rates, which range from 0.0001 to 0.21 artifacts per year (Table 2), although it must be kept in mind that some of these early sites are still in the excavation process (e.g., La Gruta 1). The highest rate corresponds to Casa del Minero 1. Hearths or charcoal concentrations are present in these sites. In addition, most of these sites have been characterized as logistic ones.

There is variability in the frequency of utilization of local rocks, which is probably related to site function, length of stay, and availability of high-quality rock, as explained in detail below.

Local rocks, although not immediately available (sensu Meltzer 1989), were used in most of the sites. Local high-quality rocks (silicified wood, chalcedony, and opals) are the most frequently used in the deepest deposit of Piedra Museo (unit 6), with an increase in the use of immediately available rocks (Civalero and Franco 2003; Meltzer 1989) for the overlying unit 4/5 (Miotti and Cattaneo 2003). Also, rocks are mostly local in the case of Casa del Minero 1, located in an area with abundant, excellent high-quality rocks

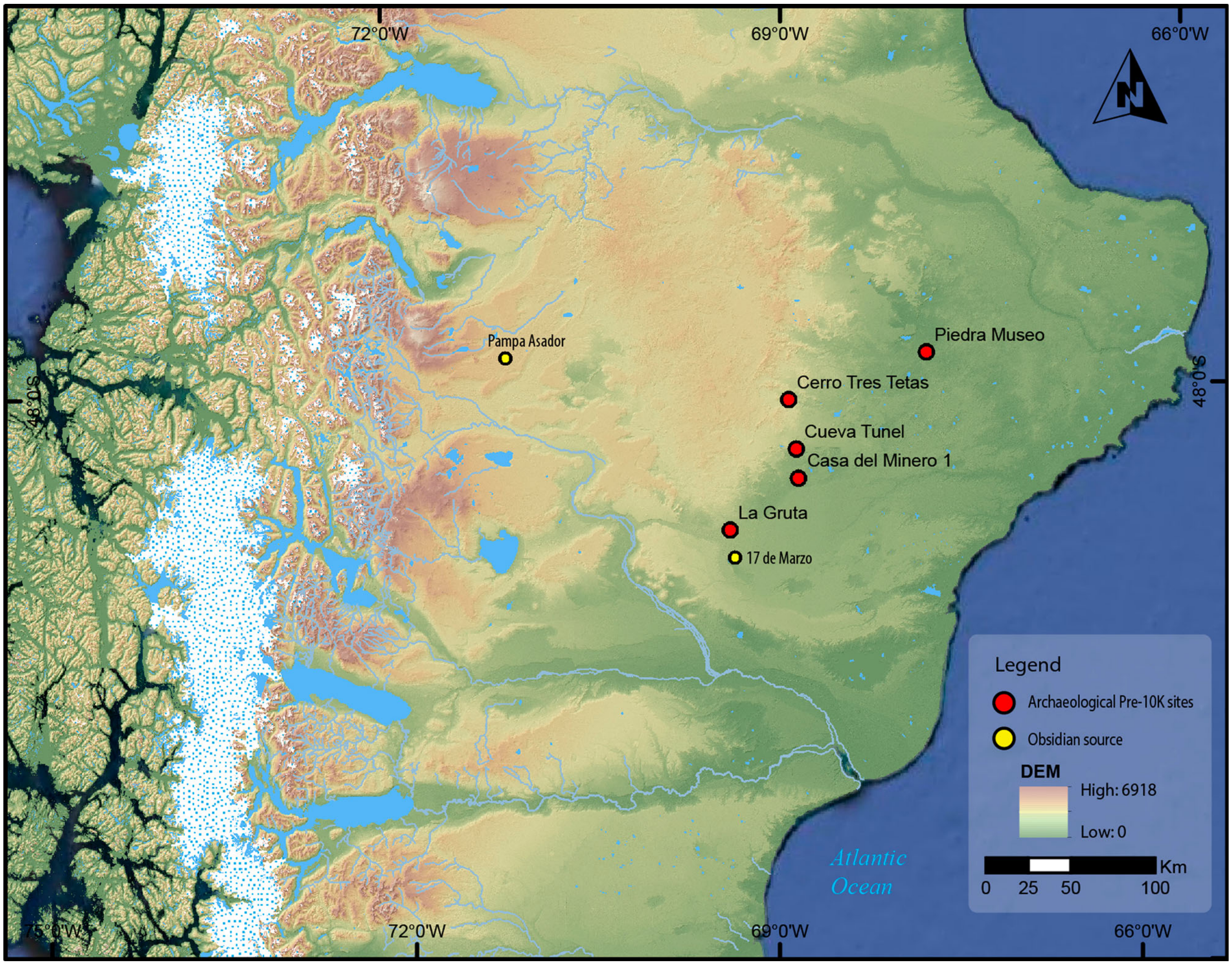


Figure 2 Sites with replicated dates earlier than 10,500 cal yr BP in the Deseado Massif (dark grey dots) and main archaeological obsidian sources (light grey dots).

(Skarbun et al. 2007). In this case, higher discard rates seem to suggest longer stays at the site. Artifacts recovered at La Gruta 1 seem to have been manufactured from distant local raw materials (i.e., distances between 10 and 40 km according to Civalero and Franco 2003). In the case of Cueva Túnel, non-local translucent opal was the rock most commonly used, and the transport of cores was identified (Skarbun 2012). High-quality local siliceous rocks were recovered as debitage, being tools probably transported to other areas (Skarbun 2012). In general, transport of rocks from and to different places was taking place, with a high frequency of local rocks, mostly those not immediately available. The clear exception is Casa del Minero, located in an area where high-quality rocks are abundant, and where longer stays probably took place.

The presence of knives and side scrapers from bifacial cores as well as the use of bifacial flakes has been recorded in the deepest deposit of Piedra Museo – unit 6 – and has been related to the utilization of generalized tools (Miotti and Cattaneo 2003). A change from this strategy to the use of standardized tools from flakes coming from cores has been identified in unit 4/5, where also two fragmented fishtail projectile points have been recovered (Miotti and Cattaneo 2003). A bifacial preform and a bifacial notch were identified at Cerro Tres Tetas, a functionally specific site (Paunero 2000). A high percentage of prepared percussion platforms is also present at the site. The presence of a bifacial preform was identified in the deepest deposit at Casa del Minero. There are last-stage bifacial reduction flakes both at Casa del Minero 1 and La Gruta 1. In the case of Piedra Museo's deepest deposit (Unit 6) and La Gruta 1, raw materials used for bifacial reduction are probably local (Franco et al. 2015; Miotti and Cattaneo 2003). In the case of La Gruta 1, they are distant local, probably coming from distances up to 25 km (Franco and Vetrisano, pers. obs.). Jennings, Pevny, and Dickens (2010) experimentally demonstrated that there are not significant differences in core efficiency between bifacial, prismatic

Table 1 Archaeological sites with calibrated dates older than 10,500 cal yr BP.

Archaeological site	Lab code	Radiocarbon date (BP)	Calibrated date (cal yr BP)	Unit	Material	Reference
Piedra Museo (a)	AA-27950	11,000 ± 65	12,713–12,994	Unit 6; bottom	Charcoal	Miotti, Salemme, and Rabassa (2003)
Piedra Museo (b)	OxA-8528	10,925 ± 65	12,685–12,928	Unit 6, bottom	Bone (*Hippidium saldiasi*); same bone as (c)	Miotti, Salemme, and Rabassa (2003)
Piedra Museo (c)	OxA-15870	10,675 ± 55	12,542–12,705	Unit 6, bottom	Bone (*Hippidium saldiasi*); same bone as (b)	Steele and Politis (2009)
Piedra Museo (d)	OxA- 9249	10,470 ± 65	12,033–12,448	Unit 5, bottom	Charcoal; same as sample (g)	Miotti, Salemme, and Rabassa (2003)
Piedra Museo (e)	Gra- 9837	10,470 ± 60	12,039–12,443	Unit 6; bottom	Charcoal	Miotti, Salemme, and Rabassa (2003)
Piedra Museo (f)	AA-8428	10,400 ± 80	11,935–12,436	Unit 5, middle	Bone (Camelidae)	Miotti, Salemme, and Rabassa (2003)
Piedra Museo (g)	AA-39367	10,400 ± 79	11,935–12,435	Unit 6, bottom	Charcoal; same as sample (d)	Steele and Politis (2009)
Piedra Museo (h)	OxA-8527	10,390 ± 70	11,938–12,430	Unit 6, middle	Bone (*Lama guanicoe*)	Miotti, Salemme, and Rabassa (2003)
Piedra Museo (i)	OxA-9507	10,100 + 110	11,265–11,965	Unit 6	Bone (*Lama*?)	Steele and Politis (2009)
Piedra Museo (k)	AA-39362	9952 ± 97	11,176–11,755	Unit 6	Bone (*Hippidium saldiasi*)	Steele and Politis (2009)
Piedra Museo (l)	OxA-9509	9950 ± 75	11,195–11,628	Unit 6 or 5/6	Charcoal	Steele and Politis (2009)
Piedra Museo (m)	LP-859	9710 ± 105	10,708–11,246	Unit 4 (bottom)	Bone (*Lama guanicoe*)	Miotti, Salemme, and Rabassa (2003)
Cerro Tres Tetas (a)	LP-525	11,560 ± 150	13,072–13,623	Unit 5 (lower)	Charcoal; same as samples (e) and (f) (see Steele and Politis 2009).	Paunero (2009) (due to incongruencies in the results, this date was discarded from the analysis)
Cerro Tres Tetas (b)	OxA-10745	11,145 ± 60	12,800–13,088	No data	Charcoal; same as sample (d)	Steele and Politis (2009)
Cerro Tres Tetas (c)	AA-22233	11,100 ± 150	12,701–13,188	Unit 5; lower	No data	Paunero (2003a)
Cerro Tres Tetas (d)	AA-39368	11,015 ± 66	12,717–13,005	Unit 5, lower	Charcoal (Steele and Politis 2009); same as sample (b)	Paunero (2003a)
Cerro Tres Tetas (e)	OxA-9244	10,915 ± 65	12,680–12,914	Unit 5, lower	Charcoal (Steele and Politis 2009); same as samples (a) and (f)	Paunero (2003a)
Cerro Tres Tetas (f)	AA-39366	10,853 ± 70	12,645–12,831	Unit 5, lower	Charcoal (Steele and Politis 2009); same as samples (a) and (e)	Paunero (2003a)
Cerro Tres Tetas (g)	LP-781	10,850 ± 150	12,427–13,048	Unit 5; lower	No data	Paunero (2003a)
Cerro Tres Tetas (h)	LP-800	10,260 ± 110	11,591–12,404	Unit 5; upper	Charcoal	Paunero (2003a)
Cueva Túnel (a)	AA-82496	10,510 ± 100	12,026–12,650	Unit 8	Bone (Camelidae, De Porras 2010)	Paunero et al. (2015)
Cueva Túnel (b)	LP-1965	10,420 ± 180	11,601–12,690	Unit 8	Bone (Lama sp., De Porras 2010)	Paunero (2009)
Cueva Túnel (c)	AA-71147	10,408 ± 59	11,989–12,425	Unit 10	Charcoal (De Porras 2010)	Paunero et al. (2015); Skarbun (2009)
Cueva Túnel (d)	AA-71148	10,400 ± 100	11,819–12,450	Unit 10	Bone (*Hippidium salidasi*, De Porras 2010)	Paunero et al. (2015); Skarbun (2009)
Casa del Minero (a)	AA-37207	10,999 ± 55	12,716–12,980	Unit 4	Probably charcoal	Paunero et al. (2007)
Casa del Minero (b)	AA-37208	10,967 ± 55	12,704–12,952	Unit 4	Probably charcoal	Paunero et al. (2007)
Casa del Minero (c)	AA-45705	10,250 ± 110	11,401–12,299	Unit 3c	No data	Paunero et al. (2007)
La Gruta 1 (a)	AA-84224	10,845 ± 61	12,650–12,801	Unit A	Charcoal	Franco et al. (2010)
La Gruta 1 (b)	AA-84223	10,840 ± 62	12,650–12,801	Unit A	Charcoal	Franco et al. (2010)
La Gruta 1 (c)	UGAMS-7538	10,790 ± 30	12,663–12,730	Unit A	Charcoal	Franco et al. (2013)
La Gruta 1 (d)	UGAMS-12428	10,720 ± 30	12,633–12,711	Unit A	Charcoal	Brook et al. (2015)
La Gruta 1 (e)	AA-76792	10,656 ± 54	12,538–12,692	Unit A	Charcoal	Franco et al. (2010)
La Gruta 1 (f)	AA-84225	10,477 ± 56	12,049–12,444	Unit A	Charcoal	Franco et al. (2010)

blade, and wedge-shaped blade core reduction, although the efficiency of bifacial and blade cores decreased with initial core weight. However, bifaces are versatile tools (Nelson 1991), and their utility can be linked not only to their potential to be used as cores, but also to their capacity to be shaped into different kinds of tools, as the already mentioned findings from Piedra Museo Unit 6 suggests.

Black obsidian is present in only two sites: La Gruta 1 (Franco et al. 2010, 2015) and Cerro Tres Tetas (Paunero 2003a). Both sites are located more than 100 km from the Pampa del Asador source (Belardi et al. 2006; Cueto, Frank, and Skarbun 2018; Espinosa and Goñi 1999; Stern 2000). The distance from Tres Tetas to the Pampa del Asador and 17 de Marzo sources is almost the same; however, La Gruta 1 is located only 12 km from the latter (Franco et al. 2017). Although Cueto, Frank, and Skarbun (2018) attribute a small obsidian artifact (less than 2 mm in length) from Cerro Tres Tetas to Pampa del Asador, they did not consider into their analysis the alternative source of 17 de Marzo, with a similar composition (Franco et al. 2017). In fact, it can come from any of the sources.

In general we can say that the occupational penecontemporaneity, along with the very low artifact discard rates, suggest the presence of small and highly mobile groups, with very short stays at each site (Brook et al. 2015; Franco et al. 2010; see also Paunero 2009). At

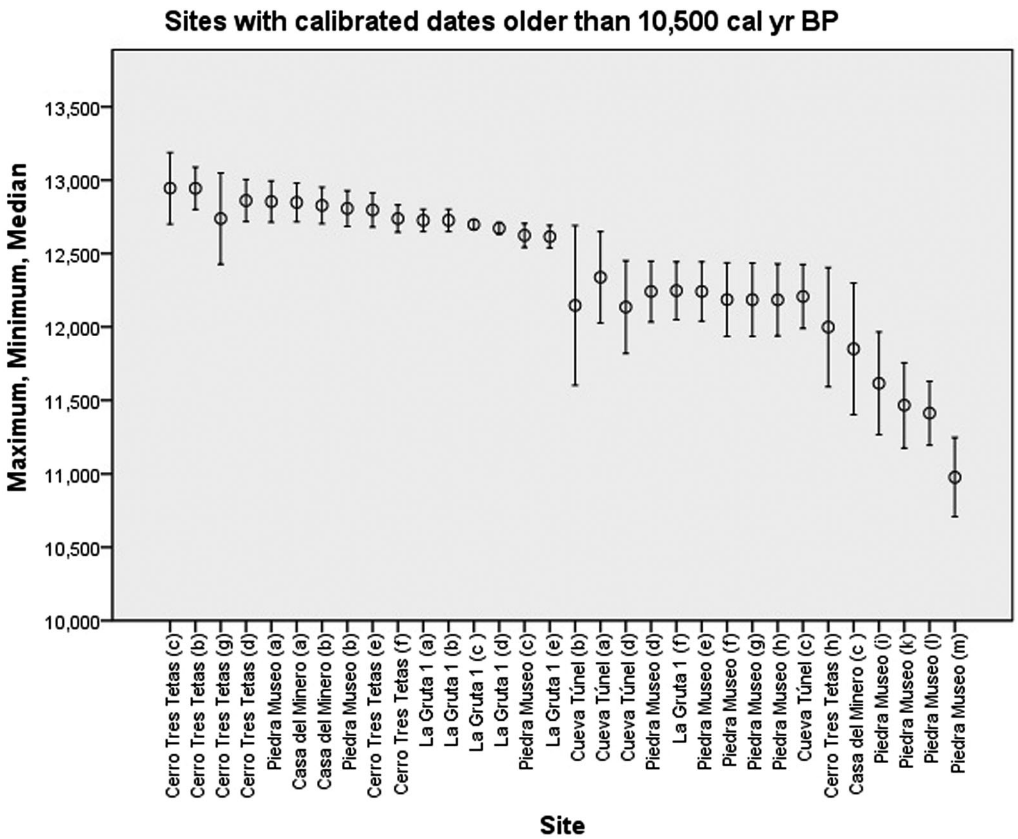


Figure 3 Dates prior to 10,500 cal yr BP in the Deseado Massif. Dates are arranged in chronological order, from the oldest to the youngest.

this time, bifaces were part of the transported tool kit (Borrero and Franco 1997). As mentioned, bifaces can be used in different ways, as cores or tools (see Goodyear 1989), or as long-life use tools (Kelly 1988). Transporting bifaces can be useful when the location of the resources is not known and their versatility (sensu Nelson 1991) would be important for highly-mobile hunter-gatherers. Also, they serve to solve inconsistencies in the distribution of resources (Meltzer 2009). In the case of the Deseado Massif, high-quality rocks are frequent, although they are not evenly distributed (Franco et al. 2015; Hermo 2008), and the need to have raw materials of excellent quality, along with transportability (sensu Nelson 1991), may be the reason for their transport. We totally agree with different researchers (Brantingham et al. 2000; Eren et al. 2014) that up to a limit, raw-

Table 2 Main variables analyzed and distance to probable water sources. Artifact rates are calculated on the basis of Cattaneo (2005), Franco et al. (2010, 2015), Miotti (1992), Paunero (2003a, 2003b), Skarbun (2009), Skarbun et al. (2015).

Site	Discard rate per m^2 per year	Hearths and charcoal concentrations	Black obsidian presence	Excavated surface (m^2)	Nearest probable water source
Cerro Tres Tetas	Artifacts: 0.046 Tools: 0.0027	Yes	Yes (Paunero 2003a)	12.25 (Paunero 2000)	110 m to a current water source
Cueva Túnel	Artifacts: 0.077 Tools: 0.0036	Yes	No	17.25 (Skarbun et al. 2015)	75 m from a lower area that collects water
Casa del Minero 1, units 4 and 3c	Artifacts: 0.21 Tools: 0.01	Yes	No	15.32 (Paunero et al. 2007)	29 m to a temporary gully (5.83 m above it) and 1.360 m to a big temporary lagoon (Paunero et al. 2007)
Piedra Museo U6	Artifacts: 0.00181 Tools: 0.00020	Yes	No	Around 50 (Miotti, Salemme, and Rabassa 2003)	Close to a gully, which flows into a big lagoon, currently without water (Miotti, Salemme, and Rabassa 2003)
Piedra Museo U4/5	Artifacts: 0.00173 Tools: 0.00047	Yes	No	Around 50 (Miotti, Salemme, and Rabassa 2003)	Close to a gully, which flows into a big lagoon, currently without water (Miotti, Salemme, and Rabassa 2003)
La Gruta 1	Artifacts: 0.06 Tools: 0	Yes	Yes (Franco et al. 2010)	1 (Brook et al. 2015; Franco et al. 2010)	Located by a current temporary pond

material differences are not a factor explaining tool morphology. However, as different flintknappers have pointed out, there is an effect of the quality of raw materials in the flintknapping process (for example Callahan 1979; Nami 1986). There are also implications for differential transport, resharpening, or discard distances related to this quality variation (i.e., Cortegoso 2008; Goodyear 1989; Smith 2015; Tomasso and Pourraz 2016), and for those reasons we believe that each case should be analyzed in detail. The quality of the raw material, sometimes improved through heat-treatment, seems to have been important during early colonization times (e.g., Collins 1999; Goodyear 1989; Meltzer 2009). In the case of our study area, high-quality siliceous rocks of unknown origin have been recovered in two caches (Franco et al. 2011, 2018).

The percentage of local raw material probably varies according to the function and length of the stay at each site, as well as to the existence of high-quality raw materials in the area where the sites are located. In our case, siliceous raw materials probably coming from nearby places are introduced into different sites. High quantities of excellent siliceous rocks immediately available were recovered at Casa del Minero, and transport of raw materials from this site to other places was also identified. Bifacial artifacts have been recovered in different sites, and in some cases they have been used as blanks for different tools. With reference to black obsidian, in the case of La Gruta 1 the secondary nearby source of 17 de Marzo (located 12 km from La Gruta; Franco et al. 2017) was probably used, obtained during regular hunter-gatherer activities. It should be mentioned that, due to the presence of this distal obsidian secondary source, the presence of other secondary sources of this obsidian cannot be discarded (Franco et al. 2017).

Remarkable is the frequency of early sites in the Deseado Massif, as has already been pointed out (i.e., Borrero 1989–90; Miotti and Cattaneo 2003; Miotti and Salemme 2004; Paunero 2009; Salemme and Miotti 2008). Miotti and Salemme (2004) attribute this

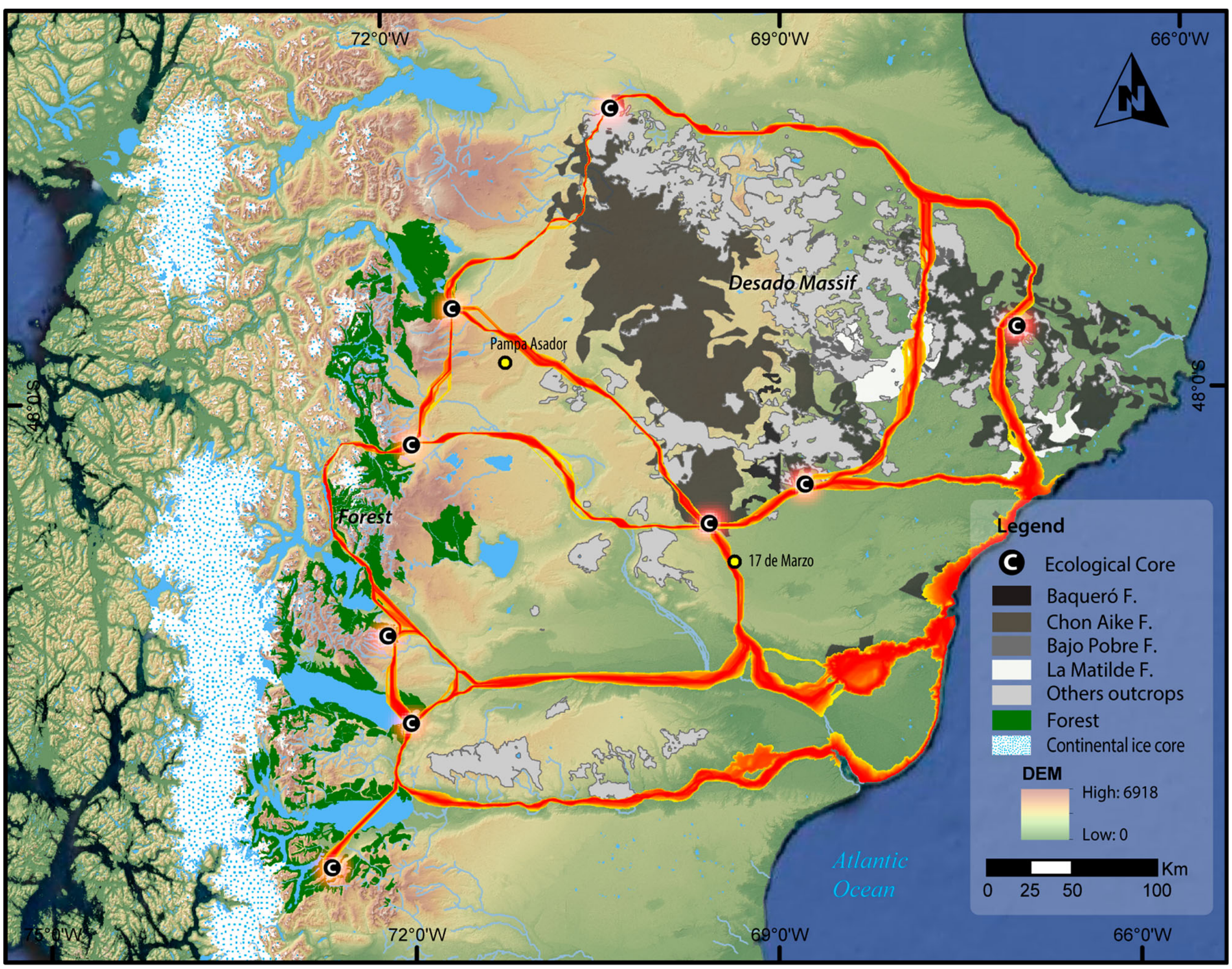


Figure 4 Corridors between ecological cores © with probable water sources before 10,500 cal yr BP and geological formations with high-quality siliceous rocks in the Deseado Massif. Dots indicate secondary black obsidian sources.

frequency to a restricted mobility related to resource concentration. We are going to analyze the case in greater depth.

4.2. Site location

As mentioned, to analyze site locations, corridors were set up between ecological cores, which were located in places with permanent and semi-permanent water supplies (rivers and places close to the forest). In addition, in the southern Deseado Massif early human presence occurred during a more humid period. Because of this reason, cores were set up where simulation models indicate the presence of streams. In particular, because of the results of the simulation models and the general slope of the surface (see Franco et al. 2018), two core areas were set up at the eastern and southern side of the Deseado Massif. Figure 4 indicates the location of these cores as well as the geological formations containing siliceous rocks of excellent quality, and corridors between them. It is worth mentioning that most of these sites are located close to paleo-lagoons, ponds, or streams that do not have water today or that only have it occasionally (Table 2). Where human occupations occurred during a more humid period (for example, in the southern Deseado Massif), it is probable that they had water.

As can be seen, there is a fairly good relationship between sites with early chronologies and these corridors, as well as between ecological corridors and LCP (Figure 5), suggesting that water and associated resources were important, as it has been already suggested (among others, Borrero 1994–95, 2005; Miotti and Salemme 2004). The exceptions are Cerro Tres Tetas – which is the oldest known archaeological site – and Cueva Túnel, around 45 and 14 km away from the corridors, respectively. Although dates for water sources have still not been obtained, Cerro Tres Tetas is located around 110 m from a modern spring, and Cueva Túnel is around 75 m from a low area which collects water from several

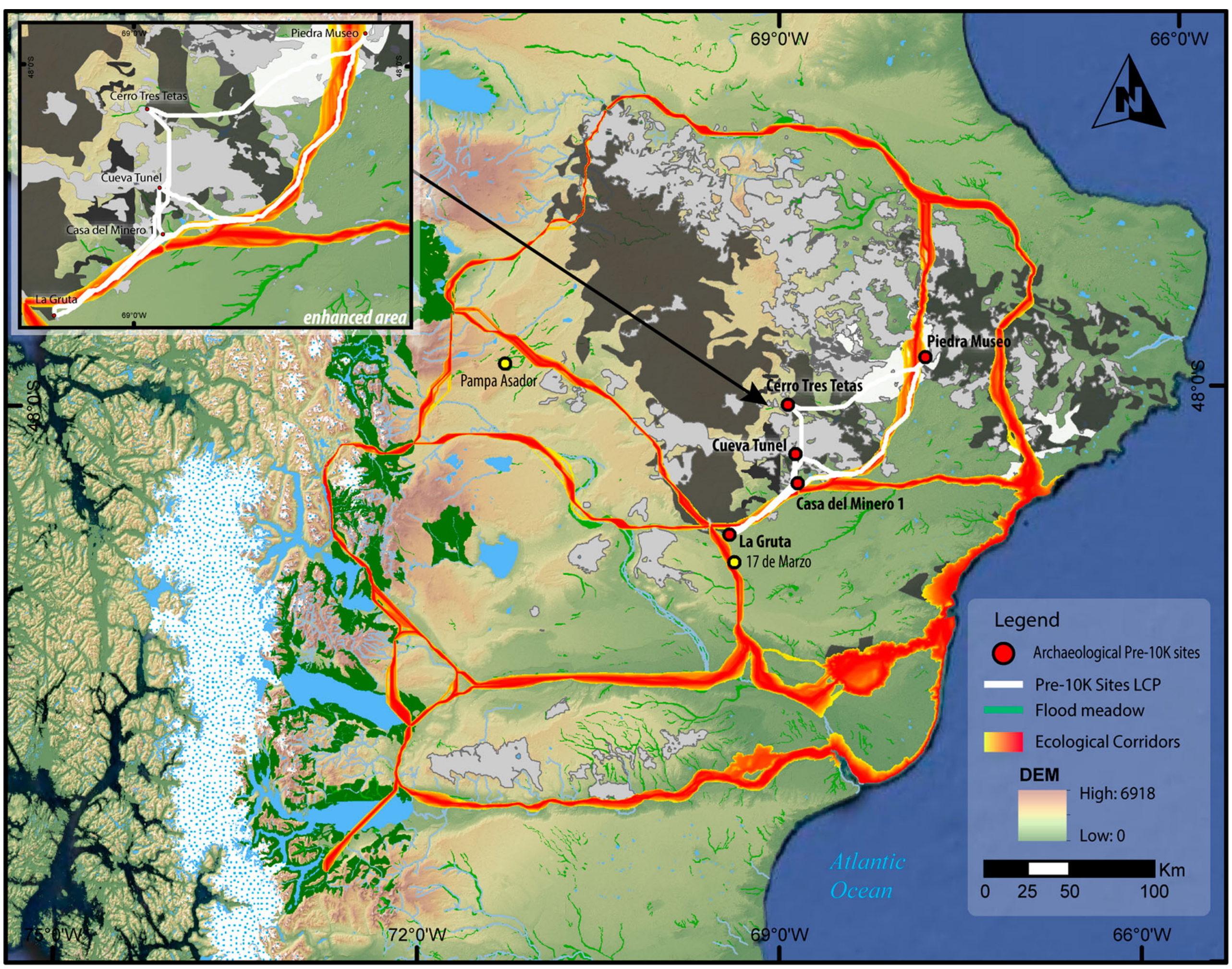


Figure 5 Early sites in the Deseado Massif and least-cost paths between them. Corridors among cores as well as rock formations with high-quality siliceous rocks present in the area are also indicated.

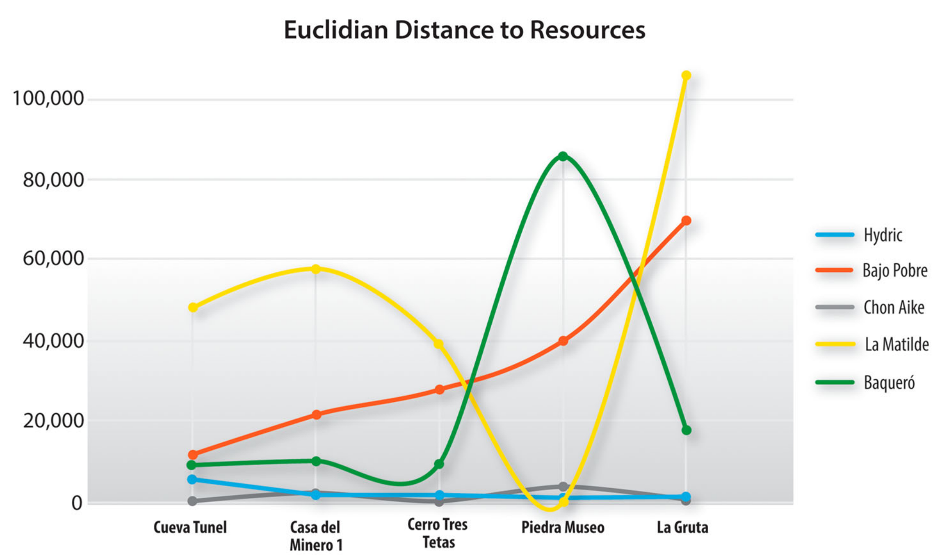
small canyons (see Table 2). It is interesting to note that the 17 de Marzo secondary obsidian source is located within one of these natural corridors, reinforcing the possibility of human provisioning of obsidian during regular activities.

Excellent rock quality may also have attracted early hunter-gatherers, as has also been suggested for North America, although there is still not agreement about the existence of special provisioning trips (e.g., Ellis 2011; Goodyear 1989; Meltzer 2009). To evaluate their importance in Patagonia, we analyzed the distribution of sites in relation to high-quality siliceous rocks at a regional scale. In this sense, it is worth mentioning that there are variations in high-quality siliceous rocks at smaller scales (Cattaneo 2004; Franco et al. 2015; Hermo 2008; Miotti and Cattaneo 2003). These scales, however, are within the proposed home-ranges of terrestrial hunter-gatherers at these latitudes (Binford 2001; Kelly 1995).

It can be seen that early archaeological sites are located in places with drinking water, but also along the border of the Deseado Massif, where high-quality rocks can be obtained (Figure 5). It should be mentioned that until now, early archaeological sites were found neither close to the Atlantic Ocean nor in the interior of the Deseado Massif. In our case, while corridors (grey gradient) border the Deseado Massif, least-cost paths (in white) suggest movements into the interior (see details in Figure 5). The lack of differences in resources between the massif and nearby spaces, with the exception of high-quality siliceous rocks, suggests that these regular activities are probably related to raw material provisioning.

There is minimal variation in Euclidean distance data between archaeological sites and resources, which is statistically shown in Figure 6. The distance cost to water resources is low, with the exception of Cueva Túnel. It should be mentioned, however, that there could have been a local source of water during initial occupations. On the other hand, this site is located a short distance from high-quality rocks, being greater in the case of the other sites – located closer to water. In addition, La Gruta 1 has the highest distance values to lithic resources, which could explain the behavior of tool caching (see Franco et al. 2011, 2018).

According to the available evidence, humans were exploiting the area of the Deseado Massif for more than 2000 years, with almost no evidence of early human presence in nearby places to the south and east. It is probable that during this time, logistical movements to environments located to the east and south had taken place, but there is no support for this idea. Other permanent water sources are present to the south (i.e., Chico River), and they were probably found during regular



	Cueva Tunel	Casa del Minero 1	Cerro Tres Tetas	Piedra Museo	La Gruta
Baqueró	9200	10,113	9381	85,700	17,700
La Matilde	48,300	57,900	39,200	192	106,000
Chon Aike	200	1800	180	3400	465
Bajo Pobre	11,600	21,600	27,900	40,000	69,400
Hydric	5490	2009	1138	849	1088

Measurement units in meters

Figure 6 Euclidian distances to water ecological cores and geological formations with high-quality rocks. Distances are in meters.

hunter-gatherer activities. However, high-quality rocks are not that abundant to the south. For example, chalcedonies are present only as small cobbles and are not predictable in their location (Franco et al. 2015).

5. Summary and discussion

Sites which can be attributed to the initial peopling of this area are located at the border of the Deseado Massif. This area continued to be used for more than 2000 years, with people moving back and forth probably using half-radius movements (Binford 1982). There are no other sites with similar chronologies in nearby places. This mobility system is expected given the short stays represented at each place and the general homogeneity of the local environment in terms of shelter, water, rocks, and perhaps fuel.

The general synchrony, the discard rates, and the signs of artifact transport would suggest highly mobile hunter-gatherers, making and carrying bifaces as part of their tool kit. Bifaces and flakes obtained from bifaces were made on high-quality siliceous rocks, sometimes heat-treated (Frank 2012; Miotti and Cattaneo 2003; Vetrisano and Franco 2017), which suggest their importance. Due to the short transport distances implied, it is probable that biface utilization was related to its transportability (sensu Nelson 1991) and the lack of knowledge of specific places where high-quality lithic sources could be found within the Deseado Massif itself, thus as a way to solve inconsistencies in resource location (see also Kelly 2003b; Meltzer 2003, 2009). Contrary to what was recorded by Eren and Andrews (2013) for the Lower Great Lakes, in the massif, bifaces were transported and used for tool blanks for knives or side scrapers in some cases (Piedra Museo U6), while in others only last-stage bifacial debitage was recovered, and it is not possible to know which kinds of tools (La Gruta 1) were being manufactured. Distances between sites are not long, but we also cannot assume direct movements between them. In our case, the transport of bifaces seems to have been taking place also sometime after the initial colonization began, when they were deposited in caches. A similar pattern was observed in North America during Clovis times (i.e., Collins 1999; Deller, Ellis, and Keron 2009; Waters and Jennings 2011). Our data suggest local movements, probably within short distances, consistent at least in the southern end of the Massif with the suggested half-radius continuous pattern of movement.

Note

1. Radiocarbon ages were calibrated at the two-sigma probability level in calendar years BP (cal yr BP) using CALIB 7.0 (Stuiver and Reimer 1993) and the Southern Hemisphere (SHcal13) atmospheric calibration curve of Hogg et al. (2013).

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