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Primary and secondary lithic raw material sources along the western coast of San Matías Gulf (Río Negro province, Argentina): A first approach to their spatial variability

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A B S T R A C T

In this article we present a first description of lithic raw material sources, and their particular geological and geomorphological characteristics, from the south part of the western coast of San Matías Gulf. The study area lineally covers ~125 km of the west coast of Río Negro province, Patagonia, Argentina (from 40°48′3.22″S, 65°4′15.77″W to 41°55′43.60″S, 65°3′50.15″W). The sources uncovered include concentrations of different types of shingle to primary outcrop, which is an exceptional find considering that to date all known sources along the western and the northern coasts of the Gulf were secondary.

As a result we now know about a considerable number of rock types of varying quality for knapping, as well as their differential distribution across space. This allows us, for the first time in our study area, to study procurement and exploitation strategies for these raw materials and also to briefly discuss the existing contrasts in rock availability across different sectors of space. The results of these studies suggest that the differential representation of these rocks in the archaeological record across space was related to variations in their spatial and temporal availability, which in turn was tied to the very formation process of the coastal archaeological record of this north Patagonian area.

1. Introduction

The study of lithic raw material sources constitutes a first building block towards any study characterizing the technological strategies undertaken by a particular society (Ericson, 1984). Once it has been accomplished, it is then possible to address such diverse themes as the transport of rock, the intensity of exploitation, the varied use for different types of tools, their dispersion across space, etc. (Torrence, 1983; Parry and Kelly, 1987; Beck and Jones, 1990; Andrefsky, 1994; Beck et al., 2002; among others). In the case of the northern coast of San Matías Gulf (Río Negro, Argentina) the study of lithic sources has only revealed the existence of secondary sources; these are principally composed of volcanic and sedimentary rocks, and to a lesser extent band pyroclastic rocks (Favier Dubois and Alberti, in press). According to existing studies (Alberti, 2012; among others), the quality of these rocks vary from bad to excellent, although those of good or very good quality predominate.

In contrast, until recently our knowledge of available lithic sources along the western coast of San Matías Gulf was perfunctory (Cardillo and Scartascini, 2007; Manzi et al., 2011), describing mainland various silica rocks recovered from secondary deposits. Based on fieldwork undertaken during 2012 and 2013, we were able to identify new sources of rock useful for knapping. One of these sources was primary and it evidenced clear signs of exploitation and use. The raw material extracted from this source was found heterogeneously distributed across space leading to the formulation of hypothesis concerning the varying access to this outcrop by human groups through time.

In this article we present for the first time data concerning primary and secondary sources in the western coast of San Matías Gulf (Fig. 1) and their relation to lithic artifacts that we have systematically sampled from the region. We placed particular emphasis on the study of the primary source of silicified tuff and the spatial distribution of artifacts made from this rock. This research combined an analysis of categorical data and the use of multivariate statistics.

2. General background

The western coast of San Matías Gulf extends from San Antonio Oeste city to Puerto Lobos where it borders with Chubut province (see Fig. 1). This coast stretches from north to south, with its main

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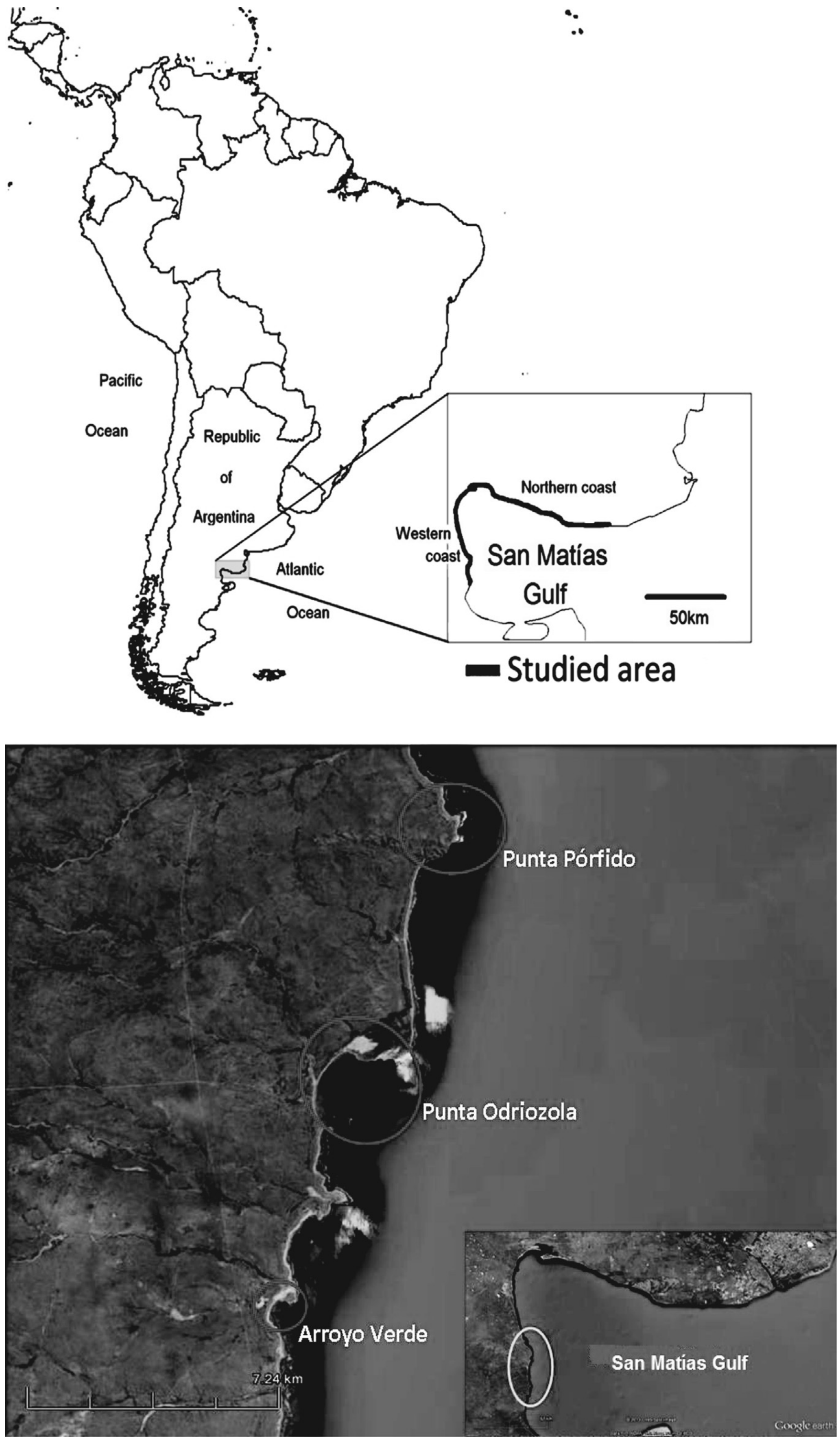

Fig. 1. Western coast of San Matías Gulf showing the areas surveyed and discussed in this article.

geological feature being the Somuncurá Plateau. The Somuncurá Plateau is a lava structure that descends to the sea in a series of flank pediments (González Díaz and Malagnino, 1984). Aside from this particular geoform, in the southern portion of the coast a volcanic environment predominates, interrupted in certain areas by estuaries with sand beaches and dunes (Favier Dubois et al., 2008; Favier Dubois and Borella, 2011).

Combining the use of geological charts for the area and previous work undertaken by members of our research group (De Alba, 1964; Cortés, 1987; Busteros et al., 1998; Martínez et al., 2001; Cardillo and Scartascini, 2007, 2011), we have identified the existence of both primary and secondary sources of rocks. The information from the geological charts and research in the area demonstrated the presence of various raw material sources that might have been exploited by the various groups who inhabited it. For example, different geologists (Ramos, 1975; Nakayama et al., 1978; Cortés, 1981, 1987; Weber, 1983; Gelós et al., 1990, 1992; Busteros et al., 1998; Martínez et al., 2001) have mentioned the presence of two important geological formations: the Marifil Volcanic Complex (see Gelós et al., 1990) composed mainly of rhyolite, dacite and rhyolite tuff with occasion obsidian cobbles, that appears discontinuously all along the coast, and the Tehuelche Formation that has been found along some of the cliff areas comprising volcanic, plutonitic, quartzite and sedimentary pebbles (Martínez et al., 2001). They have also suggested the presence of secondary deposits of phthanite with quartz and jasper, alluvial fans composed of rhyolite, granodiorites, phyllites and basalt clasts, and outcrops of different types of schist, slate and phyllites. Other rocks including quartzite, sandstone, pelite, diabase and granite were also sampled in this area (see Gelós et al., 1990; Martínez et al., 2001; among others). The fieldwork previously undertaken by our research group identified new sources of rock in our study area, such as porphyrite outcrops, veins and blocks of silica of varying quality (Cardillo and Scartascini, 2007), and secondary deposits of excellent quality cobbles of chalcedony in specific areas, such as around Verde stream (see Fig. 1) (Cardillo and Scartascini, 2007).

In respect to the archaeological material itself, in the study area we have identified 42 *loci* (discrete concentrations of artifacts) to date, with the majority of these concentrated in the northern sector, where we have dunes, littoral corridors and terraced levels (Favier Dubois et al., 2008; Favier Dubois and Borella, 2011). In general, the archaeology is much more visible in this sector than in the western coast given the lack of aeolian deposits along the marine terraces (Manzi et al., 2009). The dated habitation sites range between 3200 and 700 BP (Favier Dubois and Borella, 2011; Borella et al., 2013). A salient fact of the archaeological record of the western coast of San Matías Gulf, in contrast to the northern one, is the elevated presence of obsidian in archaeological sites (*loci*). The frequency of obsidian in these contexts is much higher here than along the northern coast (Favier Dubois et al., 2009). On the basis of geochemical analysis, we were able to determine that the obsidian in the northern coast sites came from Chubut province (Telsen and the Sacanana Pampa), from the Somuncurá Plateau, and from Cantera Lolog in Neuquén (see Favier Dubois et al., 2009).

3. Methods

In characterizing the raw material sources, we decided to undertake 12 directed sampling procedures based on time expended on survey and nodule quantity (Franco and Borrero, 1999). We recovered approximately 188 nodules and artifacts, chosen exclusively to characterize the sources (see Fig. 2). In addition, to study the artifact composition at identified *loci* in the western coast (in the southern part of this coast, which is the section that we took here, 11 *loci* in total) we defined quadrants of different sizes depending on the lithic deposit density. In places where the artifact density was lower, we defined larger quadrants in order to obtain a representative artifact sample. The aim was to collect data concerning the exploitation of raw material and of the artifacts manufactured from it. This was carried out only for the primary source located at Punta Odriozola area, as it is the best quality source and the only one in which artifacts manufactured from it can be identified. Also in this area, due to the high density of materials (67 artifacts per 50 cm^2), we chose to sample by area instead of by time. In the case of the metamorphic rock source detected at Punta Pórfido area, this was not possible as the materials could be pseudo-artifacts. We also excavated shell middens to recover datable material, archaeofaunal remains, and other types of material. Nevertheless, in this paper we focus mainly on the surface record. The materials coming from excavated shell middens were taking into account only in the case of the middens near to the only good-quality primary source we have found in the area, in order to detect the frequency of this type of rock in the archaeological record.

The results of the surface sampling analysis (of both raw material and archaeological assemblages) were inputted on Excel spreadsheets. An estimation of the absolute and relative frequency of the

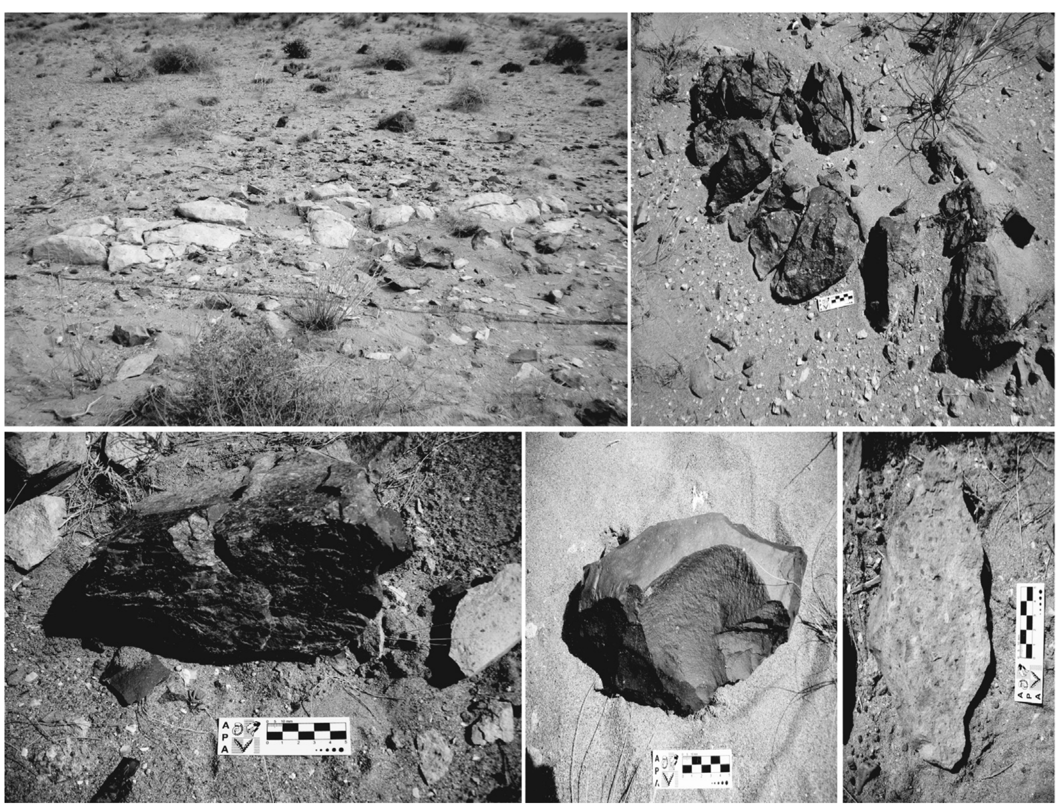

Fig. 2. Primary source with details of the different types of silicified tuff that occur in the area. Tested pieces of the tuff are shown in photos.

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types of raw material used per category of artifact (flakes, cores, implements) and the type of rock frequency (some of them identified through thin sections) in each studied area (see Table 3) was used to arrive at a preliminary characterization of exploitation strategies (Tables 1 and 2). The petrographic characterization of the rocks was done taking thin-section samples of the most important types of rocks (27 samples) that were then identified by one of the authors at the Petrographic Laboratory of the Geology Department, of the Faculty of Exact and Natural Sciences, of the Buenos Aires University. The quality of the rocks was established according to Aragón and Franco (1997) and the form of the pebbles was determined following the criteria established in Zingg (1935), modified by us.

Table 1
Rocks recovered as artifacts at the primary source sector of Punta Odriozola. DFGR: dark fine-grained rocks (sensu Charlin, 2005). This includes vitrophyrics, dacites, greandwackes, lutites and cherts, rock types identified in thin-section under a microscope. They could not be distinguished without the use of a microscope. For the northern coast this petrographic analysis allowed us to determine that these rocks had a volcanic rather than a sedimentary origin. Given that along the western coast we have yet to fully develop this type of analysis, we choose to use the term DFGR until such a time as we can conclusively determine which type of rocks have been recovered from this area of the Gulf.

Raw material	*n*	%
Sandstone	5	10.18
Chalcedony	4	8.16
Quartzite	2	4.08
Quartz	2	4.08
Jasper	1	2.04
Obsidian	1	2.04
Opal	1	2.04
DFGR	2	4.08
Acidic volcanic	6	12.24
Silica	21	42.86
Tuff	3	6.12
Xylopal	1	2.04
Total	49	100

Table 2
Absolute and relative frequency of red silicified tuff recovered from surface sites and through excavation. Only 7 *loci* are shown in the table as the other 4 that we sampled lack any artifact made of this type of raw material.

Loci	Flakes	Cores	Tools	Total	%
AV1	1	1	0	2	6.25
PO (OD7)	4	0	0	4	12.5
PO Terraza	17	1	2	20	62.5
PP Cerrito	1	0	0	1	3.12
PO – Sec2Son2 (sup.)	0	1	0	1	3.12
PP Marca 8	1	1	1	3	9.37
PO – Sec3Son1	1	0	0	1	3.12
Total	25	4	3	32	100

As the main goal of our paper is to explore the differences among the lithic raw materials exploitation, we performed multivariate analyses in order to characterize the rock selection in our study area. The multivariate procedures allow reduction of dimensionality and extraction of the general variation trends. In this case, the Pearson correlation coefficient shows raw material where richness (frequency of rock types in each *loci*) is strongly related to sample size (e.g., $r = 0.95$; $p < 0.0001$).

As in the present study, when sample conditions (sampling area, time, intensity) are not constant among areas, the use of standardization procedures to control sample size effect on richness is a very common and recommended practice in Ecology (Lepš and Šmilauer, 2003). Frequency transformation gives the same potential weight in describing the sampling units. In the present study, we use relative abundances (proportions by stone tool types) in the comparisons. The former standardization depicts class richness in relation to the total abundance of each sample, preserving relative differences among common and rare tools. In addition, the Bray–Curtis symmetric dissimilarity measure was preferred to the Euclidean one because the former takes into account only the shared tool types present (Legendre and Legendre, 1998). The equation describes changes in relative abundance and composition, where the number of classes that are unique to any of the two samples is divided by the total number of species within the two samples. The Bray–Curtis dissimilarity index varies between 0 and 1, where 0 means that the two samples have the same tool composition (share all the classes) and 1 means that the two samples do not share any tools.

Then we carried out a non-metric multidimensional scaling (MDS) analysis on raw material proportions per site. This robust and very flexible ordination method (Minchin, 1987) can be applied to different kind of data. It also allows using a wide range of distance or dissimilarity measures, including Bray–Curtis. MDS iteratively seeks a solution and stops computation when the best solution has been found. The goodness of fit of the ordination can be measured with the stress, which is a measure of the relation between the original and the predicted ordination. As a rule of thumb, stress less than 2.5 and near 0 suggests good fit (Manly, 1994). Afterwards, this distribution was contrasted against different independent variables to explore the likelihood of different factors related with the ordination. In this case, we considered whether the general tendencies observed in rock composition could be related to the spatial location of the sample (described by spatial coordinates) or to differences associated with different flint knapping activities described by flake, tool, and core proportions recovered in each *loci*. Spatial distance between *loci* was summarized by a first axis of Principal Coordinate analysis of

Table 3
Rocks recovered as artifacts at the surveyed *loci* in the western coast of San Matías Gulf. Cript: cryptocrystalline rocks (chalcedony. jasper and opal). Met: metamorphic rocks. Obs: obsidian. DFGR: dark fine-grained rocks. Sed: sedimentary rocks. Vulc: vulcanites. Xyl: xilopal. AV: Verde Stream. PO: Punta Odriozola. PO2. Punta Odriozola. Sector #2. PO3: Punta Odriozola. Sector #3. POSS: Punta Odriozola Southern Sector. POsT1: Punta Odriozola Transect 1 Sector. POsT2: Punta Odriozola Transect 2 Sector. POT: Punta Odriozola Transect. PP: Punta Pórfido. PP8: Punta Pórfido 8.

Loci	Cript.	*p*	Quartz	*p*	Met.	*p*	Obs.	*p*	DFGR	*p*	Sed.	*p*	Chert	*p*	Tuff	*p*	Vulc.	*p*	Xyl.	*p*
AV	22	0.07	1	0.13	3	0.21	1	0.04	1	0.10	24	0.20	38	0.10	2	0.01	42	0.14	0	0.00
PO	13	0.21	0	0.00	0	0.00	0	0.00	0	0.00	1	0.04	4	0.05	6	0.11	17	0.26	1	0.33
PO2	8	0.21	0	0.00	1	0.55	0	0.00	0	0.00	0	0.00	7	0.14	1	0.03	3	0.08	0	0.00
PO3	1	0.01	0	0.00	0	0.00	4	0.29	2	0.41	4	0.07	27	0.14	3	0.02	7	0.05	0	0.00
PO3m2	5	0.05	0	0.00	0	0.00	6	0.69	0	0.00	1	0.03	20	0.17	0	0.00	6	0.06	0	0.00
POSS	10	0.03	1	0.12	0	0.00	1	0.03	0	0.00	25	0.20	55	0.13	0	0.00	31	0.10	6	0.40
POsT1	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	3	0.03	57	0.88	7	0.09	0	0.00
POsT2	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.04	17	0.96	0	0.00	0	0.00
POT	34	0.21	1	0.23	1	0.13	0	0.00	0	0.00	4	0.06	9	0.04	28	0.20	23	0.14	0	0.00
PP	15	0.25	0	0.00	0	0.00	2	0.35	0	0.00	0	0.00	11	0.14	2	0.04	14	0.23	0	0.00
PP8	40	0.19	1	0.18	2	0.20	0	0.00	2	0.28	0	0.00	19	0.07	14	0.08	1	0.00	0	0.00

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latitude and longitude data of each location that explains 99.60% of geographical distances. The null hypothesis of this test says that raw material proportion is independent to tool, flake and core proportions and no spatial correlation between location and raw material discard rates could be observed at a significance level of $\alpha = 0.05$. Correlation was made *a posteriori* on the first two axis of MDS, using the lineal Pearson *r* correlation oriented in relation to the maximum variation axis explained. Explained variance was measured by squared correlations (R^2) and signification was estimated by 10.000 permutations. We used software *R* for all the statistical analysis (R Development Core Team, 2005).

4. Results

4.1. Secondary sources

4.1.1. Verde stream

The source detected in this area was not *sensu stricto* a source of raw material given that it comprised a scattering of nodules across the terraces adjacent to Verde stream (see Fig. 4). A team of four sampled the terraces and the area adjoining the coast. Due to the wide dispersion of the nodules, each sampling effort lasted approximately an hour. Eleven very good to excellent nodules (*sensu* Aragón and Franco, 1997) for knapping were collected (Fig. 4). These nodules had a ragged surface and they were tabular or sub-rounded in form (citing and modifying Zingg, 1935). On average these pebbles measured 6 cm in length (standard deviation 2 cm), 5 cm in width (standard deviation 1 cm) and 3 cm in thickness (standard deviation 1 cm). The thin-sectioning of two nodules revealed that they were composed of chert with a high concentration of acicular zebraic chalcedony. It was these properties that made them so good for knapping.

4.1.2. Punta Odriozola – South Sector

In the southern sector of Punta Odriozola, a 10 × 10 m surface sampling was undertaken on an artificially exposed cut in the ground located 100 m inland. A series of rocks ranged from bad to excellent knapping quality (Fig. 4). Amongst these were principally silicas, as well as acidic volcanites and quartz of inferior quality. The cortex of these nodules was smooth or dimpled, and they came in many different forms – disc-like, rounded, sub-rounded and tabular (cf. Zingg, 1935). On average these nodules where 5 cm in length (standard deviation 2 cm), 4 cm wide (standard deviation 2 cm) and 2 cm thick (standard deviation 1 cm). Two cobbles were thin-sectioned. One of these was composed of chalcedony formed through the penetration of a chert vein into sandstone. The second was an acidic porphyry with a significant amount of quartz, probably due to hydrothermal alteration, a common alteration in a volcanic area such as this one.

4.1.3. Punta Odriozola – primary source area

In association to a primary source of tuff, we detected a secondary source of regular quality silica for knapping. In a 5-min sampling exercise undertaken by two people, 60 nodules were collected. These nodules were predominantly tabular or sub-rounded in shape (cf. Zingg, 1935), with a ragged surface, and measuring on average 4 cm in length (standard deviation 1 cm), 3 cm in width (standard deviation 2 cm) and 2 cm thick (standard deviation 0.5 cm) (Fig. 4). We undertook a 5-min sampling and not an hour as in other cases, because of the great density of these silica nodules in the area. We estimate that in 60 min, we could have collected about 700 nodules.

4.2. Primary sources

4.2.1. Punta Odriozola – workshop area

Using a petrographic microscope to identify thin sections, we were able to determinate that the primary source is composed of lithic tuff with different degrees of silification (Fig. 2). This source had two outcrops, both of low knapping potential, but the areas in which the red tuff was most silicified its knapping quality was excellent (see Fig. 2). The burgundy colored tuff was of regular knapping quality and the most homogenous within the assemblage, in that there were no large variations in quality within the sample.

Both outcrops were small in size, with restricted spatial distribution, and limited obstrusivity on the environment. The total dispersion of material around the outcrops was approximately 90 m^2. We sampled this source so as to determine the degree of exploitation and the types of artifacts that were manufactured from this source. To this end, we collected, among other artifacts, cores that still have potential use, some of which had blade extraction scars. There was a very low number of hammers, all of which were small (see Fig. 3 for details on the distribution of these artifacts). This is odd, given that in the context of a quarry we would expect to have been able to collect a larger number of these types of tools. The sampling (50 cm^2) of the furthest outcrop (located 13 m from the one described above) yielded a large quantity of waste flakes (13) and unidentified artifacts (5).

Fig. 3. Sketch of the primary source surveyed in Punta Odriozola indicating the outcrops and the distribution of cores and hammers. In the square in the right bottom corner of the Figure we have included a portion of this outcrop which is 13 m from the main one and is out of scale.

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In this area, we also identified other types of rocks that were used in tool manufacture. In this survey we did not just collect nodules, but also cores, artifacts and knapping waste in general, given that we were focusing on detecting the introduction of other rocks into the workshop. There were a varied number of other rocks registered at the site (Table 1) with their quality for knapping varying from bad to excellent, with the predomination of excellent quality knapping material. We have sampled the types of raw material at this point, as it is the only potential source that we can positively affirm was exploited in the past. The variety of rocks that we found here probably has something to do with groups getting together at this point of the space in order to refresh their toolkits. The obsidian found at the site was of the black and grey translucide types.

This site was formed under particular circumstances (the presence of mobile sand dunes) that in turn influenced materials' dispersion and outcrop accessibility. To the east and south of the outcrop there was almost no material from this source, a pattern that was repeated in the neighboring shell midden (10 m from the outcrop), from which only one flake was recovered. Nevertheless, a higher density of artifacts on this rock was observed to the west and north. Likewise, the redder and more silicified tuff is found in archaeological *loci* at Odriozola and Punta Pórfido, as well as at Verde stream (see Table 2). The rock source found at Verde stream is slightly different, perhaps related to the existent variety within this source. The material frequency analysis in this sector suggests that the majority of the manufactured artifacts possibly made of these two types of tuff from this quarry (given the macroscopic characteristics of this rock and the absence of it in other sources of the area) were discard flakes, followed by cores and included very few tools (only three).

The dispersal of burgundy tuff has not been exactly defined given that this raw material was also found in secondary sources in other sectors of the area. It is therefore possible that this tuff could have originated from different sources.

4.2.2. Punta Odriozola — Southern Sector

Another primary source that we detected in the area was one of brown silica characterized band nodules that were breaking off from a primary outcrop (see Fig. 4). These nodules (we sampled 12 in total in an area of 5 $\times$ 5 m) were of good to excellent quality for knapping and were tabular in shape (*sensu* Zingg, 1935), measuring 5 cm in length (standard deviation 2 cm), 4 cm in width (standard deviation 2 cm) and 2 cm in thickness (standard deviation 1 cm). A detailed identification of thin-sections under a petrographic microscope showed that it was a chert, although very close to opal given that it was almost isotropic under the microscope (Limarino, personal communication, 2013).

4.2.3. Punta Pórfido — Cerrito Sector

This was a source of white silica rock of good knapping quality that appeared as a vein ~5 m long on Punta Pórfido (Fig. 4). Aside from this rock vein, we registered its presence in the form of nodules scattered on the surface. As well as this source, there were clasts scattered around the area that would seem to have originated from the degradation of Punta Pórfido. Thin-sectioning of one of these clasts revealed a rhyolite similar to a dense, high grade tuff.

4.2.4. Punta Pórfido — coastal sector

Along the coastal sector of Punta Pórfido there is a metamorphic rock outcrop source (Fig. 4) or regular knapping quality. We are unsure as to whether it is a slate or a phyllite given that the thin-

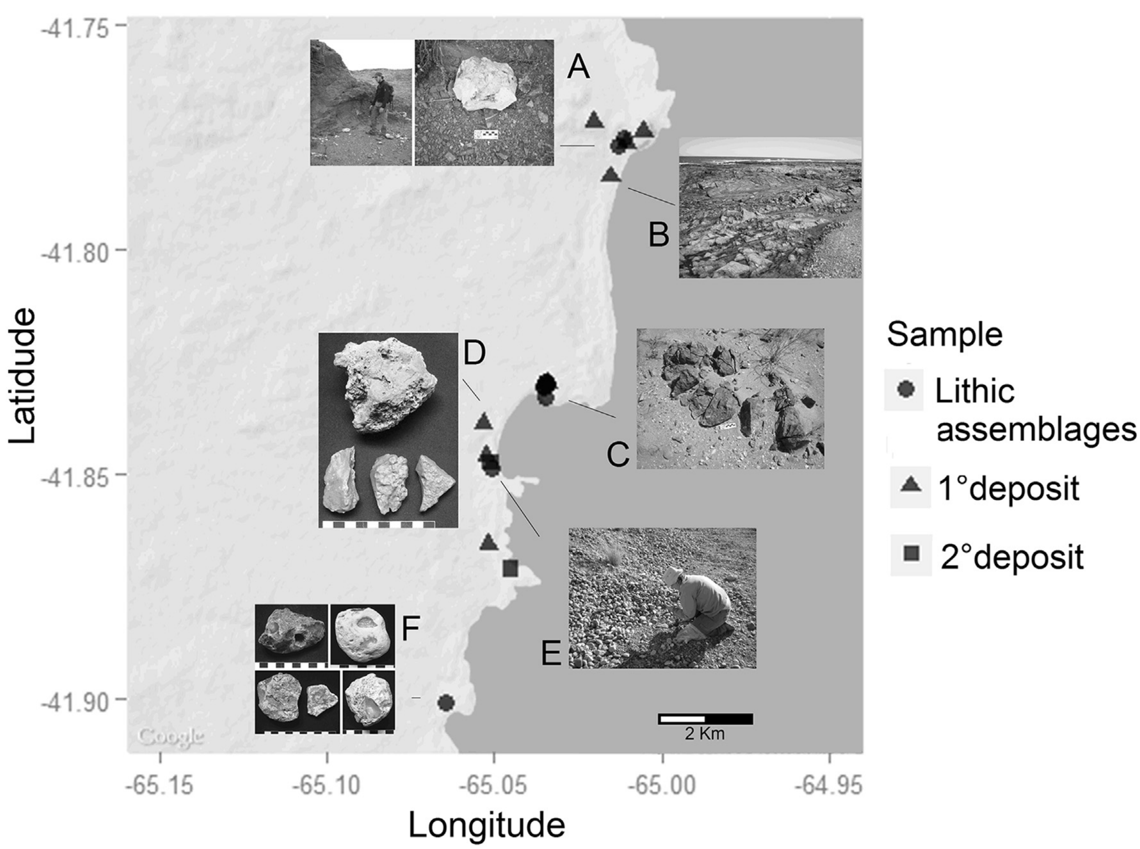

Fig. 4. Distribution of lithic assemblages, primary and secondary deposits sampled, located and surveyed in the study area. A: Punta Pórfido — Cerrito Sector. B: Punta Pórfido — Coastal sector. C: Punta Odriozola — Workshop area. D: Punta Odriozola — Southern Sector (brown silica). E: Punta Odriozola — South Sector (secondary source). F: Verde Stream.

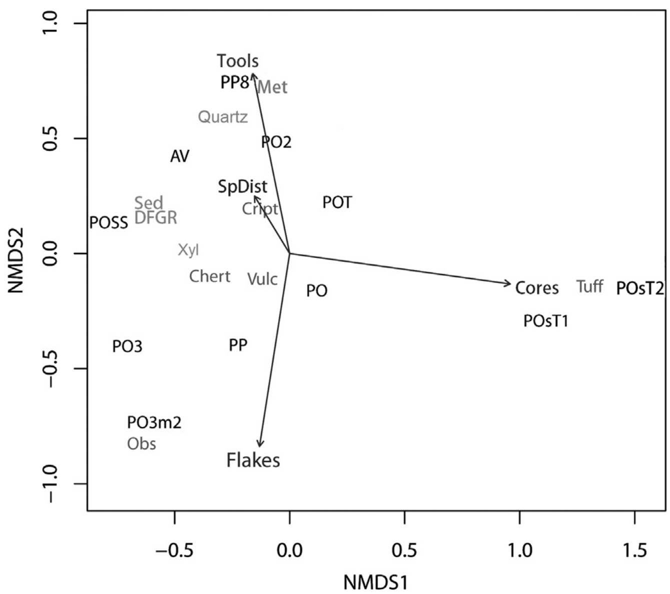

Fig. 5. MMDS analysis. Observe the *loci* distribution and the raw material frequency in each one. The curves represent estimated (and statistically significant) changes in the proportion of flakes in relation to raw materials at different sectors. The arrow shows the direction of the increasing variable value, and the length of the arrow is proportional to the correlation between the variable and the ordination. Obs: obsidian. Sed: sedimentary rocks. DFGR: dark fine-grained rocks. Vulc: vulcanites. Met: metamorphic rocks. Xyl: xylopal. Cript: cryptocrystalline rocks (chalcedony, jasper and opal). PO: Punta Odriozola. PO2. Punta Odriozola, Sector #2. PO3: Punta Odriozola, Sector #3. POSS: Punta Odriozola Southern Sector. POT: Punta Odriozola Transect. POsT1: Punta Odriozola, Transect 1 Sector. POsT2: Punta Odriozola, Transect 2 Sector. AV: Verde Stream. PP: Punta Pórfido. PP8: Punta Pórfido 8. SpDist: spatial distance between *loci*.

section is still being processed. This source was found in the intertidal zone and today is only available at low tide. On the berm can be found fragments of this rock that have fallen from the outcrop, and this rock was therefore available at all times. This outcrop measured ~800 m in length. Only an adze-like tool made from this raw material was discovered, 7 km away from this outcrop.

4.3. Other rocks identified via thin-sectioning

Apart from the samples taken from primary sources, we also analyzed nodules from different types of rocks recovered from across the study area. The aim of the thin-sectioning identification was to characterize types of rocks available for knapping activities. These rocks are very similar to the raw materials that were used for tool manufacturing at the *loci* we have studied up to now. The thin-sections of the collected nodules allowed us to identify sedimentary, volcanic, and pyroclastic rocks as well as the existence of a heavy mineral. A thin-section was undertaken on a “bola” made from this material, as no nodules of this material were recovered. Among the sedimentary rocks, we identified biogenic and hydrothermally altered cherts and chalcedony. Within the volcanic rocks we detected acidic rocks (rhyolites and dacites with different degrees of silification) and basics (basalts/andesites, trachyandesite). Finally, within the pyroclastic rocks, the most abundant in the area, we identified lithic tuffs, crystallines and glass with different degrees of fusing and silification, and also in some cases copper or iron stained. The heavy mineral was thin-sectioned twice and we identified the material as specular hematite. We would expect to see this material in the area given that there is an iron mine near the city of Sierra Grande, 55 km distant.

4.4. Statistical analysis applied to the archaeological materials

The MMDS analysis over the sampled raw materials shows the general trends in the variation of the proportions of rock types (Fig. 5). The stress = 0.12 and the correlation between original and estimated *loci* distances suggest a good ordination solution ($R^2 = 0.92$). In this manner, it should be possible to characterize certain sectors through their higher proportion of certain types of rocks. Within these, the workshop sectors (POsT1 and POsT2) revealed higher proportions of tuff. Other samples from Punta Odriozola showed higher proportions of specific types of rocks that were not common to the area, such as DFGR and obsidian.

Linear correlation between independent variables (flake $R^2 = 0.22$ $p > 0.05$, core $R^2 = 0.29$, $p > 0.05$ and tool proportion $R^2 = 0.19$, $p > 0.05$ and spatial distance between *loci* $R^2 = 0.02$, $p > 0.05$) shows no significant correlation with ordination. This result suggests that crude measures of tool production have no clear relation with rock type and site location. Spatial pattern is particularly counterintuitive in the case of Punta Odriozola location, which is very close to the high quality tuff outcrop. Only the outcrop samples have high proportion of cores, related to first phases of tool/blank production. We discuss some possible causes below.

5. Discussion and conclusions

The southern sector of the western coast of San Matías Gulf possesses primary and secondary lithic sources providing rocks of good to excellent knapping quality. Among these sources it was only possible to identify dispersion patterns for the materials from the quarry-workshop of Punta Odriozola, as it is the only one that has reliable evidence of exploitation. At this quarry-workshop we uncovered evidence for lithic reduction *in situ* through the presence of hammers, waste flakes from the first stages in the reduction of lithic blocks, prepared and partially used cores, as well as a great quantity of *debitage* from the knapping of transportable blanks. In this paper, we have paid special attention to the study of the composition and dispersion of the lithic raw materials from this primary source.

Based on our field surveys and collection of samples, we also observed that the blanks and cores from the silicified tuff quarry were transported to different sectors in the study area. Nevertheless, our sampling and excavation of the shell midden next to the quarry uncovered very few artifacts made of this raw material. This pattern is statically supported by ordination and regression results between flake, tool, core proportions, and spatial distance between locations. A logical expectation had been that the *loci* near the outcrop, like PO3 and PO3M2, would show higher proportion of tuff exploitation byproducts. Nevertheless, only outcrop samples fit this expectation. One possible explanation is that when Punta Odriozola was occupied and the shell midden was being formed, this outcrop was covered by a sand dune (there are active dunes in the area), and hence access to this raw material source would have been impossible. Additionally, we discard the hypothesis that the quarry was exhausted given that the source is still rich in usable material.

The statistical analysis suggest that there was no differential use in the types of rocks given that the same proportions of cores, flakes and tools are found across the board. In the case of the methamorphic rocks (slates) of Punta Pórfido location (e.g. PP8 in Fig. 5), it is likely that the tools were formed directly onto the metamorphic rocks, without the need of a particular reduction technique. Because of this, we cannot identify the cores easily.

The results from the multivariate analysis suggested that only the *loci* closest to the primary sources tended to have a greater proportion of the available rocks. Other samples had higher

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proportions of non-local rocks such as obsidian or cryptocrystalline rocks from secondary deposits. However, we are not clear as to the relation between the spatial distribution of the *loci* and the byproducts of knapping, or the tools. For instance, obsidian tools might not appear in the samples given that they were prized and curated. Also, given that obsidian often has a good natural edge, there might be very limited *debitage* of this material. We have recovered some small projectile points in some of the samples we have taken in some points of the area.

In this respect, an estimation of the statistical power of the minimum sample size required for reject the null hypothesis under linear assumption, shows that for us to have a significant observable Pearson's r correlation the assemblage would have to be composed of at least 30 sampling cases – this in turn would imply an 80% reliability score. Given this fact, it is necessary to increase the number of samples with the goal of detecting observable differences in rock proportions on the basis of the differential use of raw material in each locality. Similarly, the spatial distance between localities, represented numerically as a first axis of a principal coordinate analysis, also suggested that there was no particular pattern to their observed distribution: this would have had important implications concerning the use of local rocks. There are sectors in which there is a higher presence of tuffs, and others such as Punta Pórfido with a higher quantity of obsidian and dark fine-grained rocks, such as occurs along the northern Gulf coast (Favier Dubois and Alberti, in press). Other areas in the study zone had a stronger association with rocks of excellent knapping quality: obsidian, petrified wood, and silica. However, in these areas we had more flakes that manufactured tools from these raw materials. If these high-quality raw materials were intensively used, more worn-out tools discarded at these points should be expected. Instead, the higher presence of flakes of these types of rocks shows that the tools made of them were transported along the space, and probably only activities of tool rejuvenation were carried out here.

In conclusion, this analysis suggested that rock utilization along the southern sector of the western coast of San Matías Gulf did not show a marked preference for a particular type of rock, or even for the manufacture of certain tools. What we do see is the exploitation of a varied number of local rock types of different quality that were immediately available to the groups in the area. Also, it was not possible at this stage to observe a clear tendency in the use of non-local rock, such as obsidian, that had been brought here from distant areas (for a summary of the northern coast, see Favier Dubois et al., 2009). In the case of obsidian, given its excellent quality and naturally occurring edges, it is possible that it could have been used without modification, or that these tools were heavily curated, given their non-local distribution.

Finally, we believe that the results point to a relatively generalized use of high quality knapping rocks locally available and, to a lesser degree, the use of rocks such as obsidian brought in from considerable distances. Further fieldwork in the future coupled with continued lab-based analysis will add to this preliminary study into the exploitation of lithic raw material along the western coast of San Matías Gulf during the Middle and Late Holocene.

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