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Chert quarries and workshops in the Humid Pampa sub-region: New contributions on exploitation techniques and circulation through study of *chaînes opératoires*

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ABSTRACT

The study of technological organization associated with hunter-gatherers groups has been one of the topics of greatest interest in the archaeological research of the Pampean region. In this sense, the aims of this paper were to interpret the role of the Cerro Largo Formation chert in the technological practices of human groups and to discuss how this rock was used and transported in the center of the Humid Pampa sub-region during the Late Holocene. We will present the techno-morphological analysis on chert artifacts recovered from Boca de la Sierra workshop in order to identify how this stone was used at the beginning of its exploitation. Then, we will compare and discuss diverse *chaînes opérotoires* on chert found in archaeological sites located at different distances from the sources. In Boca de la Sierra workshop, we recorded three initial forms of exploitation of the nodules. The Cerro Largo Formation chert had been transported from this workshop to other sites in the form of different kinds of partially and/or totally decorticated cores, nodules, large flakes, and possibly tools. In those sites located at a short distance from the quarry workshops (Empalme Querandíes 1 and Laguna La Barrancosa 2) we observed complete *chaînes opérotoires* organized through *débitage*, with low production of standardized blank and a high frequency of external flakes used as blank for the manufacture of different kinds of tools. In those sites located at a long distance from the quarry workshops (Laguna La Larga and Laguna Seca 2), we recorded *chaînes opérotoires* developed almost entirely. Even though some expedient tools are recorded, the greatest maximization in the use of Cerro Largo Formation chert is remarkable. The high proportion of standardized, small and shaped tools, the identification of exhausted cores, the use of a bipolar technique, and the presence of resharpening flake edges show a curated technological strategy. Finally, the presence of complete *chaînes opérotoires* close to the hills allow us to infer direct access to the outcrops and an easy acquisition of chert; whereas the features observed in the other sites indicate that the chert acquisition was done by specific trips or by social exchange and interaction networks with other groups.

1. Introduction

One of the topics of greatest interest in archaeological research developed through the last years in the Pampean region of Argentina has been the study of different lithic raw material outcrops (Barros and Messineo, 2004; Bayón et al., 2006; Berón, 2006; Catella et al., 2010; Colombo, 2011; Messineo, 2011) and the way hunter-gatherer societies exploited them, in order to interpret how human groups used those resources and under what types of artifacts such rocks circulated in the Pampean landscape. In this context, the investigations that we have done in the northwestern sector of the Tandilia Hills System (center of the Humid Pampas sub-region, province of Buenos Aires) were directed at determining the local availability of lithic raw materials, with the aim of incorporate this information to the knowledge of a regional structure of lithic resources (Barros and Messineo, 2004; Messineo et al., 2004; Barros, 2009; Messineo, 2011).

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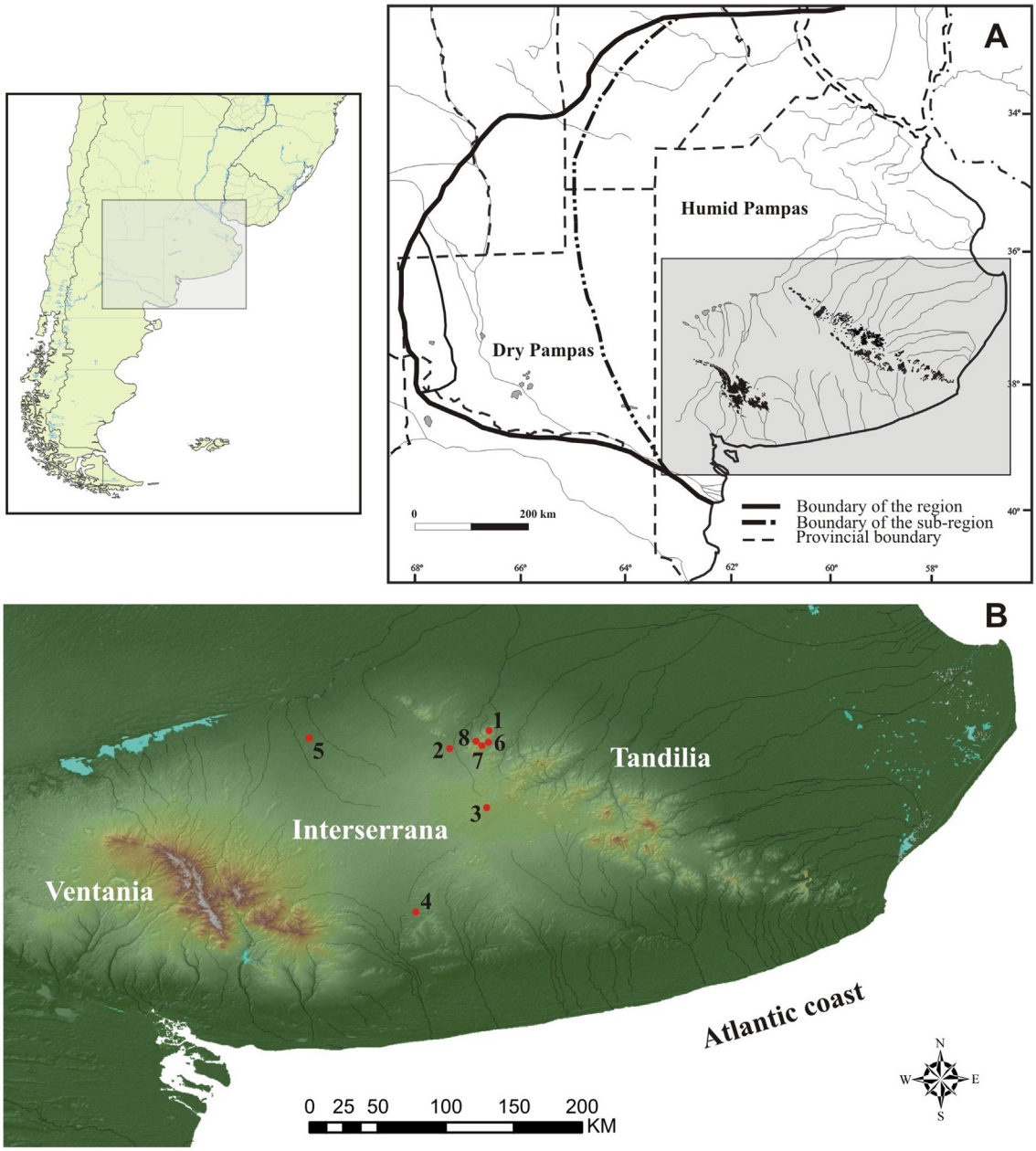

Fig. 1. Location map of the Pampean region and sites mentioned in the text: 1- Boca de la Sierra workshop; 2- Empalme Querandíes 1; 3- Laguna La Barrancosa 2; 4- Laguna La Larga; 5- Laguna Seca 2; 6- Cerro Núcleo Central 1; 7- El Mirador; 8- Cerro Tres Lomas 1.

As part of these investigations, we have conducted a series of projects aimed at gaining a better understanding of the technological organization associated at the human groups that inhabited the center of the Humid Pampas sub-region (Fig 1). First, we carried out a survey of the outcrops, for which different variables strictly related with the study of primary and secondary sources of various types of rocks were evaluated (e.g., accessibility, availability, distribution, abundance, variability, and knapping quality within the same outcrop, among others). Subsequently, we performed the technological analysis of artifacts recovered in two chert workshops (Cerro Núcleo Central 1 and El Mirador sites) and in one silicified dolomite quarry workshop (Cerro Tres Lomas 1), in order to explain how the lithic artifacts were manufactured in these sites where the stone tools reduction pathway begins (Barros and Messineo, 2004, 2006; Messineo et al., 2004; Barros, 2009). Finally, we studied the way in which these materials circulated through different environments, particularly in the upper basin of Tapalqué creek and in the middle basin of Salado creek (Messineo, 2011; Barros, 2013; Colantonio, 2013).

In reference to the main results obtained so far we can emphasize that among the lithic raw materials identified in the northwestern sector of the Tandilia Hills System, the Cerro Largo Formation chert was preferentially exploited (Messineo et al., 2004), due to it being the rock with the best knapping quality and with the highest number of areas related with its exploitation (Barros and Messineo, 2006). In turn, it represents the highest percentages in most archaeological sites located close to the hills, but it is less frequently present in those sites from the Pampean region located at greater distances (Barros and Messineo, 2004; Messineo and Barros, 2014).

Taking these studies into account, the main objective of this research was to interpret the role of the Cerro Largo Formation chert in the technological practices of human groups in a regional scale. To accomplish this objective, various *chaînes opérotoires* on chert found in archaeological sites located at different distances from the sources will be described to organize, compare, and discuss some of the ways of exploiting this rock by hunter-gatherers during the Late Holocene. Additionally, the information obtained in these sites will be used in order to discuss the strategies applied in the chert circulation associated with human mobility in the Pampa grasslands during this period.

The theoretical and methodological model followed on this work is the *chaîne opérotoire* (Leroi Gourhan, 1943; Lemonnier, 1992; Inizan et al., 1995), that studies all the processes involved in the production of lithic artifacts, from procurement to abandonment, going through a series of intermediate steps as the first stage of reduction, core preparation, flake acquisition, manufacture of tools and their use (Geneste, 1991). It also allows us to structure activities carried out by the human groups, being able to locate each *objectif de production* in a technological context and to analyze the movement of stones in a given space (Inizan et al., 1995). Furthermore, our research follows an integrated technological approach, in which the technology is considered as a cultural phenomenon closely linked to the social dynamics, which responds to environmental, economic, social, cultural, and symbolic variables (Nelson, 1991; Lemonnier, 1992; Inizan et al., 1995; Ingold, 1997; Ross et al., 2003; Topping, 2011; among others).

Before discussing the role of the Cerro Largo Formation chert in the technological organization of the hunter-gatherer groups, we will briefly review the regional and local structure (northwest sector of the Tandilia Hills System) of lithic resources, emphasizing the description of chert outcrops available for its exploitation. Also, we will present the techno-morphological analysis on chert materials recovered at the Boca de la Sierra workshop, an archaeological site recently excavated, in order to understand what types of knapping activities were performed during the beginning of their exploitation until the rock began to circulate to other sites.

2. Environmental setting and regional structure of lithic resources in the Pampa grasslands

The Pampean region is located in the eastern part of Argentina between 30° and 39° S, Uruguay, and southern Brazil (Morrone, 2001). The Pampa grassland, an extensive flat to gently undulating landscape, is the most extensive area covered by grass in Argentina. This vast plain includes two sub-regions divided by the 700–800 mm isohyet: the Dry Pampas in the west characterized by a dry steppe of moderate continental climate and the Humid Pampas in the east distinguished by a humid temperate prairie (Prieto, 2000). The latter sub-region is interrupted by the Tandilia and Ventania mountain ranges and in its southern part is connected with the coastal plain (Fig. 1A). This region is characterized by an east-west moisture gradient and increasing continentally towards the northwest. The climate is temperate, with average temperatures that range between 24 °C in summer (January–February) and 10 °C in winter (July–August) in the northeast, whereas in the southwest for the same months the average is between 20 °C and 7 °C (Burgos, 1968). Precipitation is highly seasonal with two well-defined rainy seasons, spring and fall. The annual total rainfall increases towards the east from ~400 mm in the southwest to 1000 mm or more in the northeast (Burgos, 1968; Prieto, 2000).

The procurement of stone for tools manufacture is an important subject of current research in the Pampean region. During the last decades, archaeologists began to use the theoretical perspective associated with the organization of technology and with the systems of lithic production (Nelson, 1991). This theoretical frame allowed them to study the sources of raw material provenience (outcrops, quarries, and workshops) and to analyze the strategies employed by hunter-gatherers in the procurement of lithic resources (see synthesis in Bayón and Flegenheimer, 2003; Bayón et al., 2006; Berón, 2006; Catella et al., 2010; Colombo, 2011; Messineo and Barros, 2014; among others). For the Humid-Pampas sub-region, four main areas have been used to obtain lithic resources (Fig. 1A). Extensive primary outcrops are located in the Tandilia and Ventania Range Systems, with smaller outcrops registered in the plains between them (Interserrana area). There are also secondary deposits available in some fluvial valleys and in the Atlantic coast (Bayón and Flegenheimer, 2004; Bonomo, 2005; Messineo, 2011).

The Tandilia System is a discontinuous group of hills extending northwest-southeast. It is 350 km long and 60 km wide, with the highest point reaching 525 m above sea level. The hills are separated by valleys or undulating plains. In the eastern portion of Tandilia, outcrops of fine and coarse-grained orthoquartzite from the Balcarce Formation and secondary deposits of quartz and silica were detected (Mazzanti, 1997). In the south-central sector of Tandilia, outcrops and quarry workshops of fine-grained orthoquartzite from the Sierras Bayas Group, chert, silicified dolomite, pigments, and medium-grained orthoquartzite from the Balcarce Formation were identified (Flegenheimer et al., 1996; Colombo, 2011). Quarry workshops of crystalline quartz, chert, and silicified dolomite were recognized in the northwestern sector (Messineo and Barros, 2014).

The Ventania System is a continuous range of hills. It stretches 180 km long and 60 km wide, with its highest point reaching 1247 m above sea level in the central section. In these hills, several investigators had detected primary outcrops of rhyolite (Oliva and Moirano, 1997) and primary and secondary outcrops of metaquartzite (Bayón et al., 2006). In the northwestern sector of Ventania and in the Chasicó basin, orthoquartzite, crystalline granites, siliceous chert outcrops were recognized, as well as the Tehuelche cobble layer (Oliva et al., 2006; Catella et al., 2010). In the Interserrana plain, minor outcrops of silicified tuff, quartzite sandstones, and coarse-grained quartzite (Ventania metaquartzite) were found. Another place with natural occurrence of lithic raw materials in the Pampa grasslands is the Atlantic coast that spans more than 350 km along the southern plains. The shoreline of the coast is covered with potential secondary lithic sources composed of a wide variety of siliceous rocks, basalt, rhyolite, andesite, tuff, granite, dacite, opal, volcanites, and quartzite cobbles, where several workshops were also recorded (Bonomo, 2005).

This landscape distribution shows that knapping rocks in the Humid Pampas sub-region are highly localized and heterogeneously distributed. For this reason, several researchers suggested the existence of different strategies oriented to the access, exploitation, procurement, and circulation of different lithic raw materials, necessary because hunter-gatherers had to transport stones within this region over hundreds of kilometers (Martínez and Mackie, 2003-2004; Bonomo, 2005; Barros and Messineo, 2006; Bayón et al., 2006; among others). In this sense, Bayón et al. (2006) proposed that the main rock transported and utilized by human groups who occupied the Humid Pampa sub-region (predominant in most archaeological contexts) was the fine-grained orthoquartzite of the Sierras Bayas Group, for which extensive exploitation areas have been recognized in the central-south sector of Tandilia range (Flegenheimer et al., 1996; Colombo, 2011), while other rocks from this range, Ventania, the coast, or unidentified sources have been used secondarily (Bayón and Flegenheimer, 2003; Bayón et al., 2006). Considering the Cerro Largo Formation chert, while in the archaeological sites near the outcrops (where it

is a local resource) its exploitation was developed by expedient technological strategy; in non-local contexts chert occupied a secondary place in lithic raw material preferences through a curated technological strategy (Messineo, 2011; Messineo and Barros, 2014).

3. Quarries and workshops in the northwestern sector of Tandilia

The northwest foothills of the Tandilia Hills System are characterized by a reduced area and elevation, with low tabular hills, and gentle discontinuous small hills. Based on the lithologic, stratigraphic, and structural characteristics and the formation history of the different units, the geology can be characterized as follows: 1) a Precambrian crystalline basement which constitutes an igneous-metamorphic complex that is part of Río de la Plata craton, 2) a horizontal or subhorizontal Precambrian–Palaeozoic supracortical sedimentary layer, represented by siliciclastic and carbonate sedimentary rocks, and 3) a modern filling composed of late Cenozoic sedimentary rocks, over which Quaternary deposits (loessic layer and soils) have developed (Dalla Salda et al., 2005; Poiré and Spalletti, 2005).

The granite of the crystalline basement was used by prehistoric hunter-gatherers for making grinding stone artifacts and crystalline quartz was utilized to manufacture diverse kinds of tools. Orthoquartzite has been recognized in three geological formations: Villa Mónica, Cerro Largo, and Balcarce. We can characterize this lithic raw material as a rock with a regular to poor knapping quality. Debris with cortex remains, large cores, and tools of different qualities indicate its possible local exploitation (Messineo, 2011). Silicified dolomite is found in very restricted areas of the Tres Lomas, Aguirre, and Largo hills (Barros and Messineo, 2006; Barros, 2009). In Tres Lomas hill, the 2 m-thick outcrop corresponding to the silicified dolomite level was composed of blocks and nodules of different sizes.

Chert has been recognized in three stratigraphic levels within the Precambric/Paleozoic sedimentary sequence of Sierras Bayas. The first and third chert levels (Villa Mónica and Loma Negra Formations, respectively) do not crop out naturally. The second chert level of the Cerro Largo Formation appears as a lens, 2 m thick, that crops out on every hill (e.g., Aguirre, Largo, Tres Lomas, etc.) and has associated archaeological quarries and workshops with high densities of knapped materials (Fig. 1B). However, the distribution of this level in slopes is not continuous and homogeneous, but rather the identified exposures stick out in isolation in several areas in the hills due to resistance against erosion (Barros and Messineo, 2006; Messineo, 2011; Messineo and Barros, 2014; among others).

Taking into account the characteristics observed in the quarry-workshops analyzed in our previous research, we can describe some particularities associated with the Cerro Largo Formation chert. This rock has a high availability, is abundant, with excellent knapping quality, and outcrops are easily accessible with a short probable time for searching and procurement. Unmodified, good quality chert nodule transportation would have been frequent, as chert outcrops in several hills. The activities carried out at these sites were related to the selection and acquisition (i.e., nodule and block testing) of blanks, the first stages of lithic reduction sequence, core exploitation, and tool manufacture. Nodules with appropriate shapes and volumes were worked with no previous preparation by unipolar reduction and direct percussion with a hard hammerstone. Among cores, percussion platforms correspond to cortical and flat surfaces and without platform preparation. In relation to the reduction type, the unifacial technique was applied to all the assemblages. Another task performed was the non-standardized flake production to manufacture some tools (e.g., end scrapers, *cepillos* -thick end scrapers-, burins, notched points, and gravers, among others) preferable with marginal retouches, while some flakes were selected to be directly used (Messineo, 2011; Messineo and Barros, 2014). Use-wear analyzes were performed by Dr. Nélida Pal over the whole of the tools found at some the quarry-workshop sites (e.g., Cerro Núcleo Central 1). However, this study indicated that the tool edges were completely modified by sedimentary abrasion and soil sheen and they did not show any diagnostic features associated with use (Pal, 2009 personal communication).

4. Boca de la Sierra workshop site

4.1. Field activities

The investigations in the sector of Boca de la Sierra (Aguirre hill, Sierras Bayas) were performed during 2009 in the context of an agreement between the Faculty of Social Sciences (UNICEN) and the Municipality of Olavarría. One of the first activities was the survey of the crest and the slope of the Aguirre hill as well as the profiles exposed as a result of the sediment movement carried out by a mining company (Fig. 2). In this sector of the hill, we recognized diverse chert outcrops. Most are discontinuously distributed across the steep slope of the hill, because the chert breccias (2 m thick) of Cerro Largo Formation stick out in isolation due to resistance against erosion. In some cases, the outcrop is represented by a roughly horizontal vein of solid chert (20–40 cm thick) with various meters of extent, and associated with a large amount of detached blocks composed of chert nodules with excellent quality for knapping (Fig. 2).

Moreover, the surveys in the vicinity of the outcrop allowed us to recognize three archaeological sites in the Locality called Boca de la Sierra (Figs. 1 and 3). One is a rocky cavity without sediment inside which was carved in the upper orthoquartzite of the Sierras Bayas Group. In this site, some flakes, debris, and stone tools, including a small triangular projectile point manufactured in chert, were found. The second site is a rock shelter located adjacently to the rocky cavity. Although we have not carried out archaeological excavations yet, abundant lithic materials were found on the surface of this shelter. The third site is Boca de la Sierra workshop, which exhibited a high density of chert artifacts. This site is about 100 m away from the outcrop (Messineo and Kaufmann, 2009).

As a quarry might potentially yield millions of bits of chert debris, it was decided not to attempt full excavation of the Boca de la Sierra workshop site. Instead, two activities were carried out. The first one was a test pit of 0.50 × 0.50 m in length and width, 1.00 m deep, excavated through ten artificial layers of 10 cm each one. Secondly, we recovered a chert artifact sample of the surface, re-exposed as a result of the road constructions carried out by mining companies. These archaeological materials were previously buried in A Horizon of soil and located next to the excavated workshop. This soil, approximately 1 m thick covering hill slopes, corresponds to aeolian deposits belonging to the La Postrera Formation, developed during almost the entire Holocene (Messineo and Barros, 2014).

At both sectors, a large quantity of lithic artifacts greater than 1.5 cm was recovered, 1025 from the surface and 1121 from the test pit (small chip stones were not counted but are represented by thousands of pieces). The excavation of the pit allows us to observe that the higher density of the material corresponds to the upper levels (73.3% in the first 20 cm) and that this density decreases from the 40 cm depth (10.5% from 40 to 90 cm depth). Throughout the profile, very small red and yellow mineral pigments were recorded ($n = 120$). We also found a piece of glass and a gastropod, introduced in the last 200 years (0–10 cm depth layer), a bone fragment

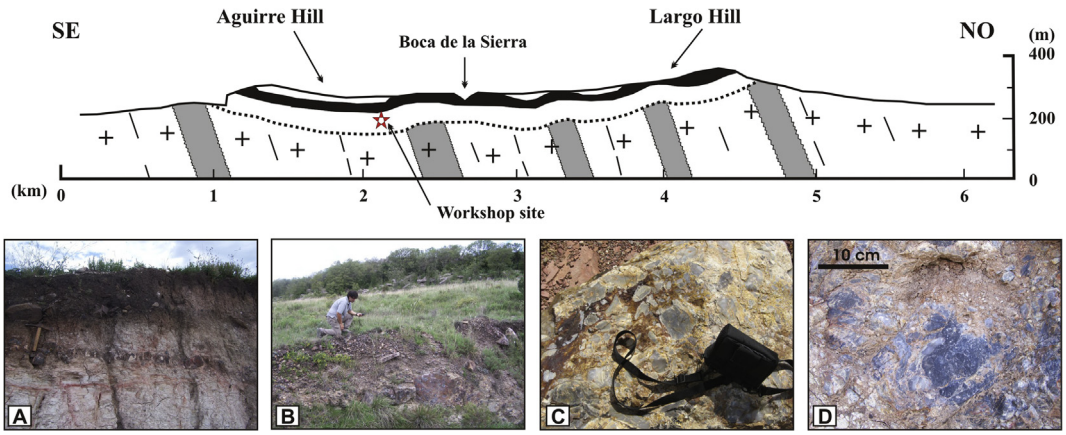

Fig. 2. Boca de la Sierra profile (Sierras Bayas hills) and chert outcrops: A- horizontal vein of solid chert; B- Horizon of soil with archaeological material; C- white translucent chert nodules; D- grey and black chert breccia.

Fig. 3. Boca de la Sierra Locality: A- rocky cavity; B- rock shelter; C- workshop site.

from a modern faunal species (30–40 cm layer), and a piece of charcoal between 70 and 80 cm depth.

4.2. Methodology

Our fieldwork was followed by the laboratory analysis of the lithic materials (flakes, debris, cores, and tools). In order to understand the methods used for extraction of the chert in this workshop, we considered both typological and technological approaches. The first is understood as a systematic description, classification and selection of different lithic artifacts (Aschero and Hocsman, 2004). The second approach is presented as a method of dynamic analysis of the static archaeological facts, where the main goal is to describe the gestures implemented during the lithic manufacture (Inizan et al., 1995). Through the study of the different stages of the *chaîne opératoire*, we can come to a better understanding of the knapping methods (*débitage*|*façonnage*) and the *objectifs de production* (Perlès, 1991).

Taking these into account, we considered morphological, technological, and dimensional attributes of the lithic artifacts, as proposed by several authors (Aschero, 1983; Bellelli et al., 1985–87; Andrefsky, 1994, 2009; Cobb and Webb, 1994; Inizan et al., 1995; Pelegrin, 1995; Aschero and Hocsman, 2004; among others). However, given the extent of this work, only some of the variables will be described, such as quantitative (e.g., length, width, thickness, and others) and qualitative ones (e.g., raw material, artifact portion, percent dorsal cortex, flakes, core and tool types, platform preparation, and others).

4.3. Results

At both sectors, the predominant raw material is chert with 2140 artifacts (99.9% in the test pit and 99.5% on the surface). Other raw materials are quartzite (five flakes) and silicified dolomite (one flake with heat treatment). All chert artifacts from the Boca de la Sierra workshop site correspond to the so-called 'Cerro Largo Formation'. This raw material occurs in many colors, including black, grey, and a white translucent with a more waxy sheen, being the most common varieties (Fig. 2). This chert is riddled with fissures and fault-planes, sometimes affecting the flaking properties of this resource negatively. In total, 73.2% of the chert assemblage greater than 1.5 cm from both sets corresponds to flakes and blades, whereas 20.9% is chunks, 2.5% is cores, 2.6% is tools, and 0.8% is nodules (Table 1). For this techno-morphological study, a sample of about 45% of all lithic artifacts (cores, tools, and flakes) recovered in both sets was analyzed.

Table 1
General chert artifact found in Boca de la Sierra workshop.

Categories	Quantity			Per cent		
	Surface	Test pit	Total	Surface	Test pit	Total
Flakes	180	501	681	67.4	74.7	72.6
Blades	4	2	6	1.5	0.3	0.6
Chunks	46	150	196	17.2	22.4	20.9
Tools	14	10	24	5.2	1.5	2.6
Cores	8	3	11	3.0	0.4	1.2
Core fragments	9	3	12	3.4	0.4	1.3
Tested nodules	1	1	2	0.4	0.15	0.2
Nodules	5	1	6	1.9	0.15	0.6
Total	267	671	938	100	100	100

4.3.1. Cores

During the analysis, 11 chert cores, 12 core fragments, and two tested nodules were identified in the sample (Table 1). The exploitation techniques were observed through study of tested nodules, decortications flakes and cores, which had in many cases remnants of the original nodule. Overall, and depending on the properties of the raw material, we recorded three initial forms of exploitation of the nodules, although in most selection of flat surfaces was performed. The first two cases (less frequent) are those associated with the extraction of blade-like flakes, one with an unprepared platform and the other with preparation. The third case corresponds to those cores from which short and wide flakes have been removed (Fig. 4).

In most of the complete cores analyzed (72.7%), we observed a single percussion platform (unidirectional scars), which may be cortical or correspond to a fracture plane linked to a fissure (Fig. 5). Of these cores, both blade-like (long, parallel, and regular flaking) and short-wide flakes extractions are identifiable on the periphery. Most of the cores were worked by unipolar direct percussion with a hard hammerstone. At lower frequencies (27.3%), we recorded cores with two, three, or more percussion platforms represented by both independent and opposed *débitage* surfaces (in this case each *débitage* surface serves as the next percussion platform surface). In those cases where there are multiple percussion platforms (multidirectional scars), the raw material has an excellent quality since the cores do not have fracture plane or fissures that fragment the rock during the knapping process. The production target in these cores is to get flakes with different sizes and forms, without previous preparation of the platform. However, in those cores with regular extraction series of long and parallel scars, we observed the preparation of the platform. Finally, bifacial and discoidal cores made of good quality chert were recorded (Fig. 5).

4.3.2. Tools

The assemblage includes 24 chert tools (we did not find hammerstones in the sample analyzed). The identified technical class is marginal unifacial reduction (retouches that affect the edge of the pieces), and only an artifact was made by bifacial reduction. Tools with very thick sections were manufactured on flakes (with cortex and angular), chunks, and cores. Only two tools are based on blade-like. These latter two are generally metric rather than qualitative because they rarely have parallel dorsal arises. In Boca de la Sierra workshop, the best represented tool types are flakes with edge-retouch (20.8%) and end scrapers (16.7%), followed by burins (12.5%), notches (8.3%), multipurpose (8.3%), *piece esquillée* (4.2%), and tool fragments (8.3%). Most of these retouched pieces are expedient tools. We also recognized flakes with some form of edge-modification (20.8%), but in some cases the retouch was discontinuous (Fig. 6). All the complete tools are thick (large flakes) and they do not have any standardized size, but vary approximately between 20 mm and 100 mm, predominantly medium-small sizes (40–60 mm), followed in lesser frequencies by medium-large (60–80 mm), large (>80 mm), and small (<40 mm) sizes.

4.3.3. Debitage

The Boca de la Sierra workshop assemblage includes 687 chert flakes and blades (Table 1). In this site, complete flakes predominate (~41%), followed by distal flake fragments (~35%), and medial and proximal flakes (~12% each). The debitage is represented by flakes with different size-ranges. In complete flakes, ~61% corresponds to the small size range (20–40 mm), followed by decreasing frequencies in medium-small (40–60 mm), medium-large (60–80 mm), and large (>80 mm) ranges (~23%, 14% and 2%, respectively). Cortical flakes have the highest percentages (42.2%), followed by angular (23%), undifferentiated (19.5%), ridged (10.9%), and others in very low proportions (flat, bifacial, and bipolar). Two crested pieces were also found, indicating that preparation of cores took place at the site. Core rejuvenation flakes in the assemblage are present in very low percentages (1.5%), and some of these types correspond to *outrepassé* flakes (Fig. 7). These flakes removed a portion of the opposite platform of the core, both unifacial and bifacial platforms. Blades make up only 6 pieces, corresponding to 0.6% of all flake and blade blanks. We recognized some blade-like features, but they are incidental elongated products and not a true reflection of the activities taking place at the site (Fig. 7). The most frequent types of platform are single (50.9%), cortical (20.2%), following by dihedral (7.9%),

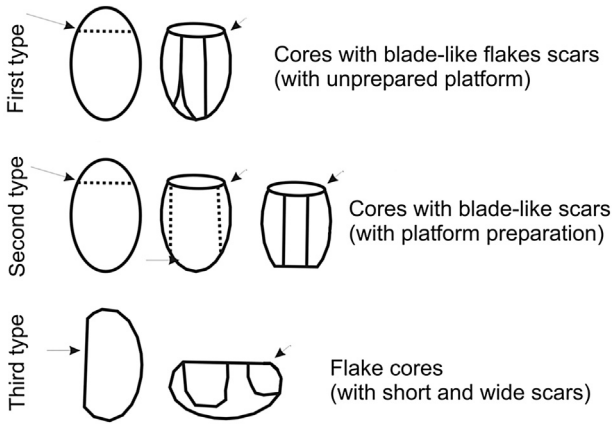

Fig. 4. Different forms to initiate the chert nodules exploitations.

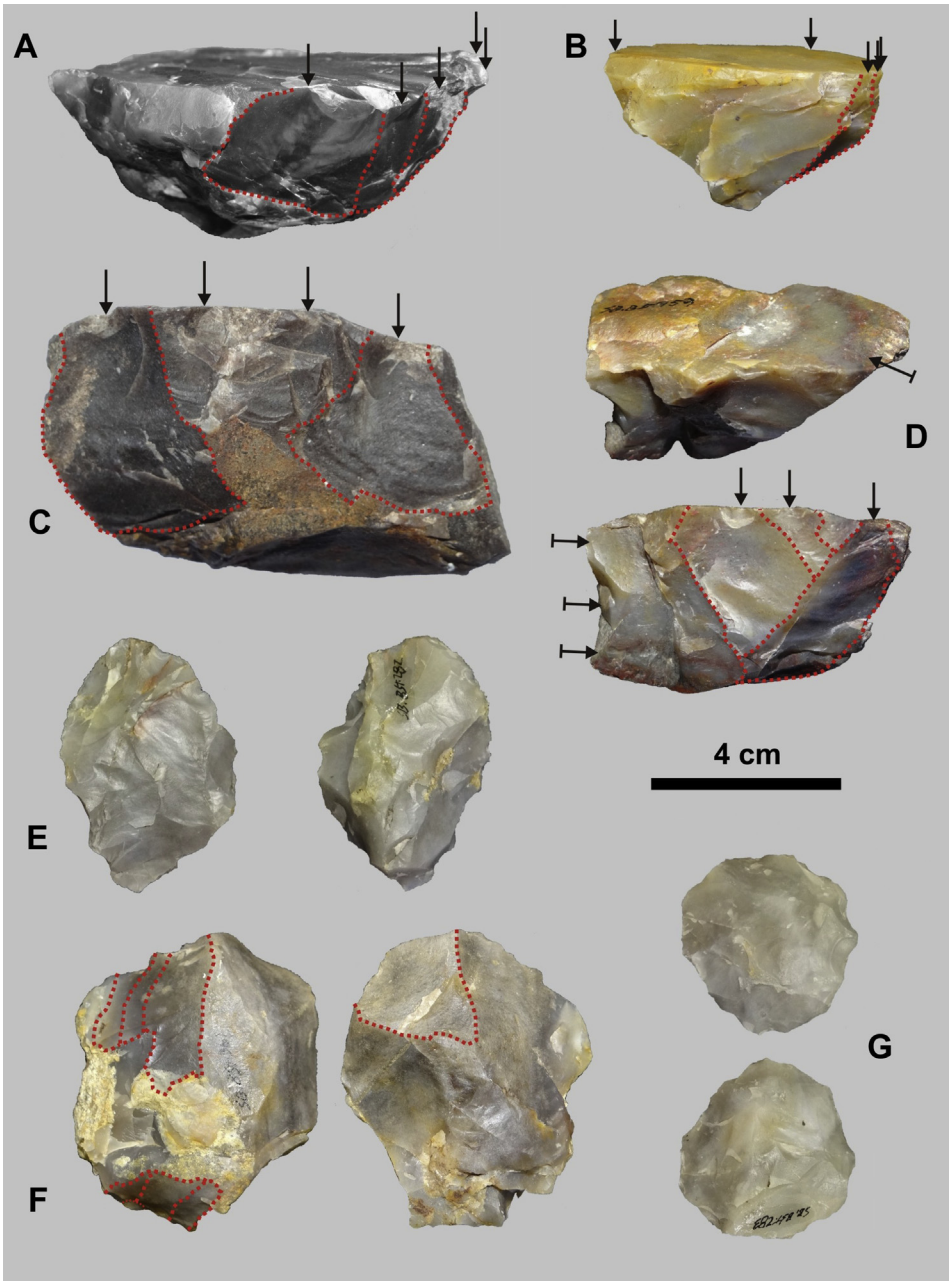

Fig. 5. Chert cores from Boca de la Sierra workshop site: B- single-platform core; A-C- cores with two percussion platforms; D- core with multiple percussion platforms and multidirectional scars; E-G- bifacial cores; F- discoidal core.

fractured (7.9%), linear (7%), faceted (3.5%), and pointed (2.6%). In 22% of the platforms, we recorded some kind of preparation such as grinding and nibbling.

5. *Chaînes opératoires* and circulation of chert in the center of the Humid Pampas sub-region

Finally, we will discuss the technological strategies identified for this raw material in four Late Holocene sites (Empalme Querandíes 1, Laguna La Barrancosa 2, Laguna La Larga, and Laguna Seca 2) located at different distances from the lithic sources, emphasizing how the Cerro Largo Formation chert arrived and how this lithic raw material was exploited and used. These four sites were selected because they present a techno-morphological study in which detailed *chaînes opératoires* were described for this lithic raw material. In the following sections we will summarize the main features of the sites (location, raw materials, and artifact groups) that are located in the center of the Humid Pampa sub-region, and we will describe the *chaînes opératoires* of chert identified in the assemblages.

5.1. Sites located at a short distance from the quarry workshops (40 km or less)

One of the sites, Empalme Querandíes 1, is located at 37°0′22.57″S; 60°22′39.28″W along Tapalqué creek (Olavarría district), in the left margin of this basin and 15 km from the quarries and workshops of the Sierras Bayas hills (Fig. 1B). Three ^{14}C dates

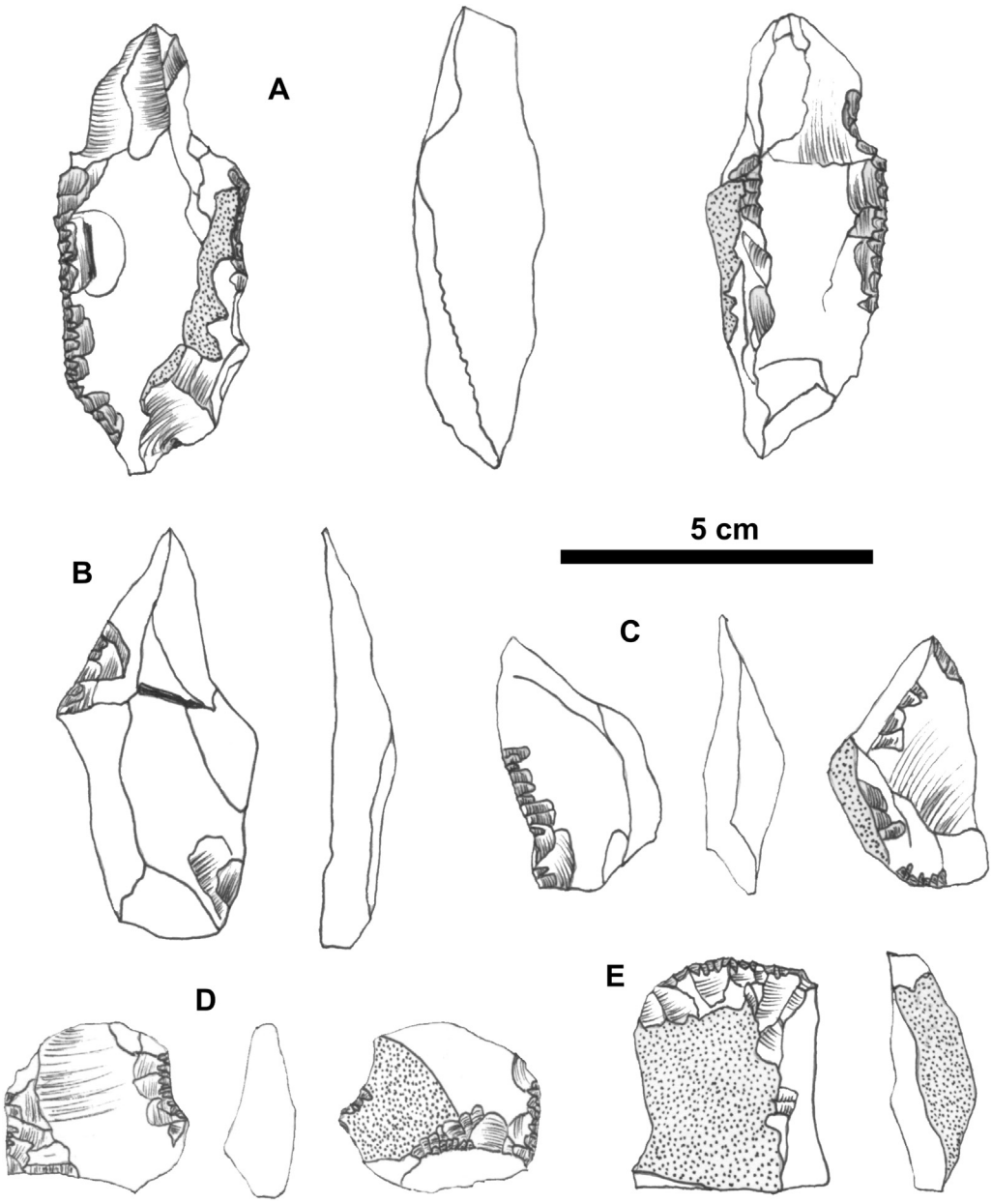

Fig. 6. Chert tools: A- multipurpose; B–C- flakes with edge-retouch; D- *piéce esquillée*; E– end-scraper.

placed the site at the beginning of the Late Holocene (between ca. 3100 and 2000 BP). A sample of 976 artifacts obtained from six grids was analyzed, which was represented mainly by orthoquartzite and chert (ca. 94%), following by silicified dolomite, granite, quartz, schist, and silica. Cerro Largo Formation chert accounts for 41.5% ($n = 406$), comprised of tools ($n = 40$), flakes ($n = 293$), cores ($n = 24$), and chunks ($n = 49$) (Colantonio, 2013; Messineo et al., 2013).

The other site, Laguna La Barrancosa 2, is located on the southern part of the homonymous lagoon at 37°20′36.66″S; 60°6′47.48″W (Benito Juárez district). This site is 40 km from the quarries and workshops of the Sierras Bayas hills (Fig. 1B). A sample of 952 artifacts was obtained from surface collection. The assemblage is represented by stones from different outcrops, mostly chert and orthoquartzite (~95%), with other rock such as silicified dolomite, quartz, basalt, methaquartzite, tuff, silica, granite, schist, and sandstone, among others. Approximately 70% ($n = 652$) corresponds to Cerro Largo Formation chert, comprised of tools ($n = 84$), flakes ($n = 542$), cores ($n = 24$), chunks ($n = 33$), and ecofacts ($n = 2$) (Messineo, 2011).

In both sites, all the stages of the *chaînes opérotoires* are represented (Fig. 8). The rock arrives at the site as natural nodules that were decorticated *in situ* or as cores partially decorticated, generating a series of flakes which are linked to the

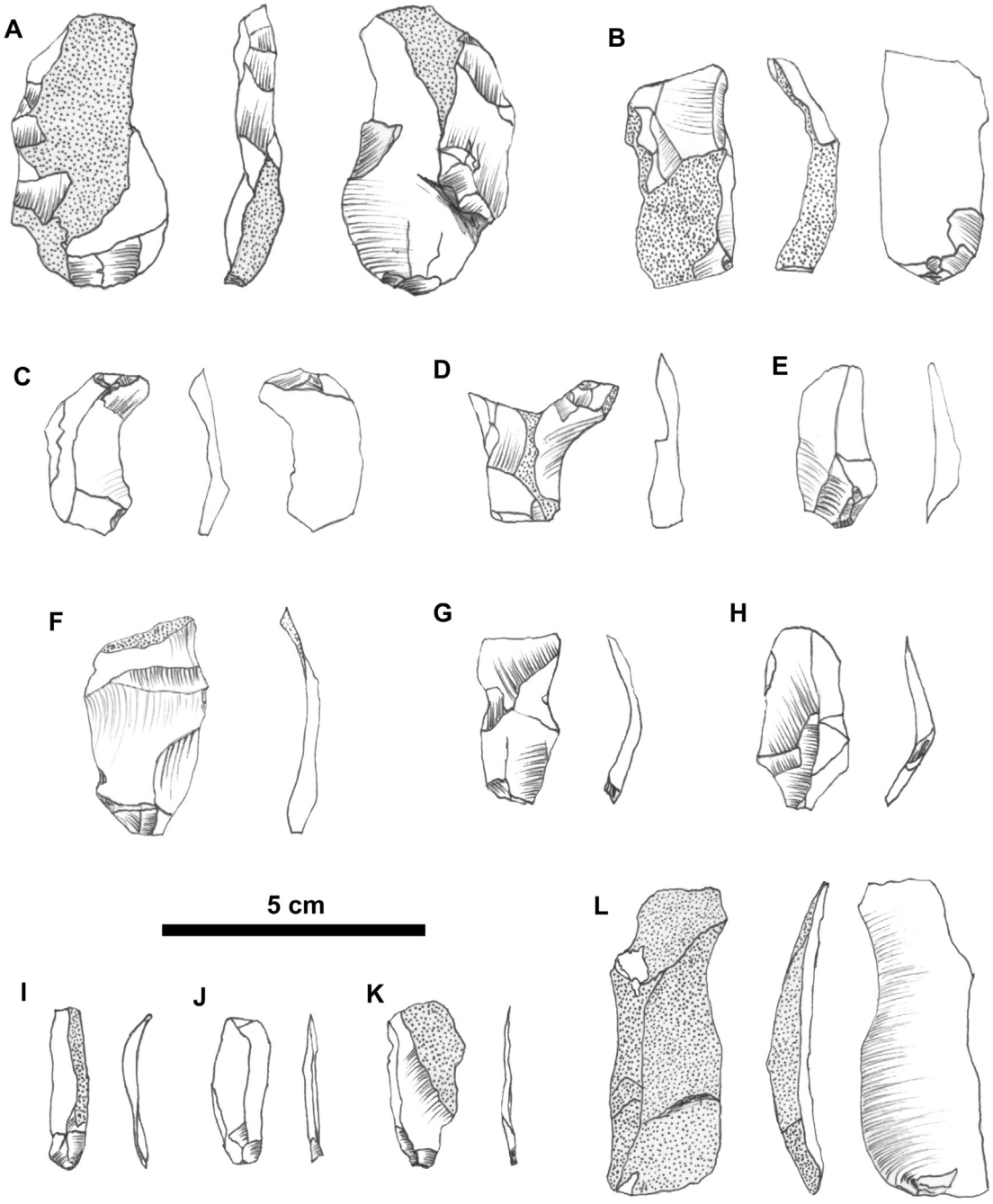

Fig. 7. Flakes and blades: A-B-C- core rejuvenation flakes (*outrepassé*); D- angular flake; E– interior flake with platform isolation; F-G-H- bifacial flakes; I-J-K-L- blade and blade-like.

early stages of the reduction sequence (e.g., high rates of cortex identified in both cores and flakes). In most cores, the platform preparation was not performed, showing the use of different platforms percussion (cores with bidirectional and multidirectional scar extractions). This allowed, along the reduction sequence, to produce different types of external and internal flakes without seeking a standardization of the tools (flakes with different thicknesses, sizes, and shapes). The flaking technique used to obtain the flake blanks was the *débitage* through hard percussion and to a lesser extent soft percussion. A high frequency of flakes could have been used as natural edges without any retouch, while in other cases we observed the manufacture of different types of tools among which are highlighted flakes with edge-retouched, end scrapers, knives, unifacial edges, and multipurpose tools, among others (Table 2). Use-wear analysis carried out on both lithic assemblages indicated that tools and flakes with natural edges processed diverse resources such as wood, leather, bone, and non-woody plants, among others (Pal and Messineo, inpress; Pal, 2014 personal communication). In relation to the manufacture of projectile points we recorded the use of *façonnage* techniques through a direct soft percussion. Also, we observed in a low frequency an advanced reduction of

the cores (exhausted and bipolar cores), a modification of the flake blanks, the resharpening of the tools, and the maintenance of the edges (Messineo, 2011; Colantonio, 2013; Messineo et al., 2013).

Table 2
Percentage of chert tool types found in the four assemblages.

Tools	EQ1 ($n = 40$)	LLB2 ($n = 76$)	LLL ($n = 35$)	LS2 ($n = 24$)
Biface	7.5	1.3	5.8	–
Knife	12.5	6.6	–	–
Unifacial edge tools	10	3.9	–	–
Pieces with edge-retouches	**15**	6.6	2.6	8.3
Projectile point	5	5.2	8.6	–
Raclettes	5	2.6	–	–
Side scraper	7.5	1.3	–	**12.5**
End scraper	10	**27.6**	**51.4**	**58.3**
Notches	–	1.3	–	4.2
Burins	–	1.3	–	4.2
Multipurpose tool	10	7.9	8.6	–
Flake with edge-modification	**17.5**	**18.4**	11.5	–
Fragment	–	15.8	**11.5**	**12.5**
Total	100	100	100	100
N° Total tools diversity[a]	10	12	6	5

[a] Fragment of tools was not considered in the total tools diversity. EQ1 (Empalme Querandíes 1), LLB2 (Laguna La Barrancosa 2), LLL (Laguna La Larga), and LS2 (Laguna Seca 2).

In summary, this lithic raw material is represented by large size debitage (flakes with high cortex presence), cores with different shapes, and great tool diversity. Also, most of the chert tools production corresponds to the *chaîne opérotoire* organized through *débitage*, with low production of standardized blanks and a high frequency of external flakes used as blanks for the manufacture of tools. All this information suggest the employment of an expedient technological strategy on Cerro Largo Formation chert that involved wide variability in core reduction, and lack of standardization in the manufacture of tools with limited modification and labor investment. Hunter-gatherer groups may have acquired this raw material directly from quarries and workshops located less than 40 km from the sites, obtaining nodules which were selected based on various criteria, such as size, shape, and raw material quality. The procurement of this chert would have been done more frequently by individuals who performed direct trips to quarries by using logistical mobility and/or during other subsistence activities (e.g., hunting or gatherer vegetables in the proximity to outcrops).

5.2. Sites located at long distances from the quarries workshops (100 km or more)

Within this group we found the Laguna La Larga site, located at 38°6′21.27″S; 60°31′38.16″W (Adolfo González Chaves district), close to the upper basin of Quequén Salado river (Madrid et al., 2002). This site is 130 km from the quarries and workshops of the Sierras Bayas hills (Fig. 1B). All the lithic archaeological materials derived from surface collections and stratigraphic pits ($n = 402$). In this assemblage we can observe a huge lithic raw material variability (e.g., orthoquartzite, methaquartzite, chert, chalcedony, basalt, sandstone, tuff, rhyolite, quartz, granite, dacite, opal, schist, and siliceous rocks) which come from diverse primary and secondary source outcrops (Tandilia, Ventania, the Atlantic coast, Dry Pampas sub-region, and others). However, orthoquartzite and chert are predominant in this assemblage (~79%). A total of 24.4% ($n = 98$) corresponds to Cerro Largo Formation chert, which is comprised by tools ($n = 35$), flakes ($n = 53$), cores ($n = 5$), and chunks ($n = 5$) (Colantonio, 2013).

Laguna Seca 2 site, is located at 37°9′9.51″S; 61°19′47.48″W (General Lamadrid district), close to the Salado creek basin (Barros,

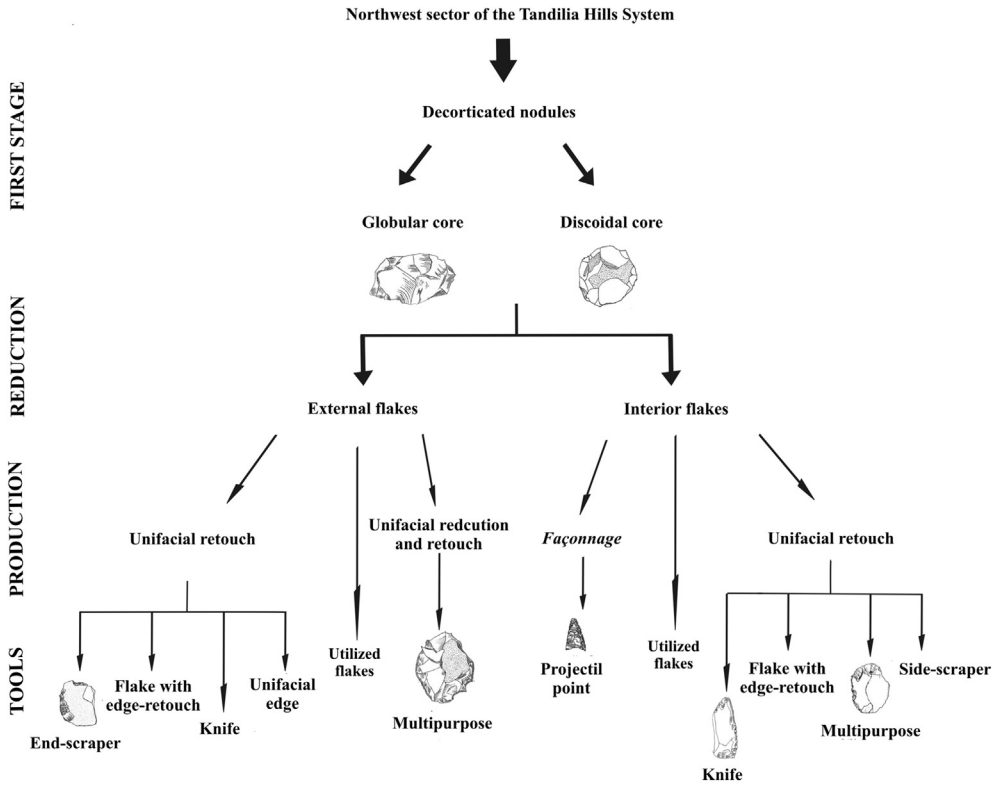

Fig. 8. *Chaîne opérotoire* from Empalme Querandíes 1 site.

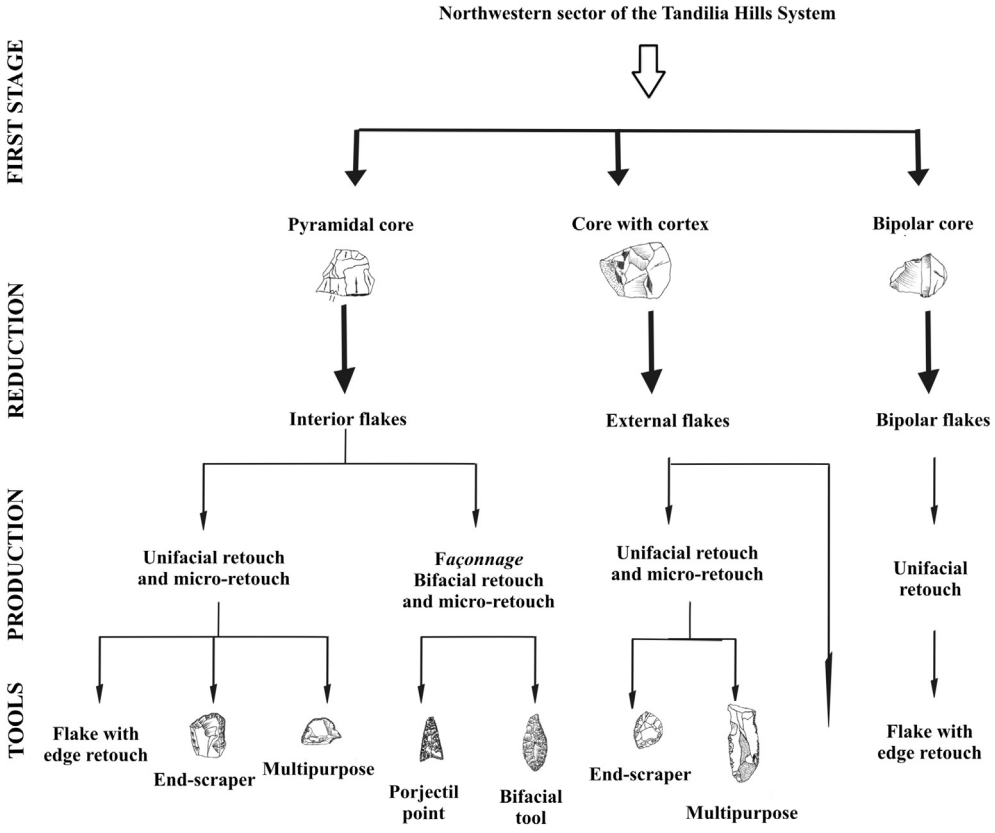

Fig. 9. *Chaîne opérotoire* from Laguna La Larga site.

2013). This site is 100 km from the quarries and workshops of the Sierras Bayas hills (Fig. 1B). All the lithic raw materials ($n = 221$) come from surface collections and they are represented by stones from different areas, mainly orthoquartzite and chert (~80%), with silicified dolomite, sandstone, rhyolite, silica, granite, quartz, and schist, among others. A total of 24.4% ($n = 54$) corresponds to Cerro Largo Formation chert, which is comprised by tools ($n = 24$), flakes ($n = 29$), and a core ($n = 1$) (Barros, 2013).

In these assemblages, we observed that *chaîne opérotoire* is developed almost entirely, starting from the presence of cores totally or partially decorticated, which were reduced by direct percussion (Fig. 9). However, unlike the sites located closer to the hills, we infer that the core decortications was not made in these locations (the percentage of cortex in cores and flakes is very low). Regarding the treatment of the cores, we recorded a maximum utilization of the raw material, which is evident in the later stages of reduction process, their small sizes, the use of bipolar reduction techniques, the presence of hinges or knapping accidents, and the high frequency of indeterminate core types. The selection of the cores in the quarry was important, because lithic raw material with good quality arrived at these sites. The Cerro Largo Formation chert would have come to these sites as cores, preforms and completed tools. The latter situation is indicated by the large number of instruments and the low representation of flakes that belong to stages of reduction and production of tools. The objective of these *chaînes opérotoires* was focused on the production of internal flakes with different sizes and shapes (to a lesser extent blade-like), generating little standardized of tool blanks (low modification through marginal unifacial retouches). With these non-standard chert flakes, the hunter-gatherers manufactured different kind of tools (e.g., end scrapers, side scrapers, pieces with edge-retouches, notches, projectile points, and burins, among others), but with a lower diversity and smaller sizes in relation to the sites located at closer distances (Tables 2 and 3). In these sites, we observed a particular selection of this raw material for producing end scrapers, where the most frequent flaking technique was the *débitage*. Also, we recorded only in Laguna La Larga low percentages of the *façonnage* method, represented by projectile points and bifacial tools. In both assemblages, we identified a predominance of direct percussion both hard and soft, but we also recognized the bipolar technique (in core fragments and flakes). Finally, one of the most frequent activities in these sites was related to the latter stages of the *chaîne opérotoire* (i.e., tool retouching and resharpening).

Table 3
Percentage of chert tools size for the four assemblages. EQ1 (Empalme Querandíes 1), LLB2 (Laguna La Barrancosa 2), LLL (Laguna La Larga), and LS2 (Laguna Seca2).

Size	EQ1 ($n = 30$)	LLB2 ($n = 29$)	LLL ($n = 27$)	LS2 ($n = 15$)
Small (<40 mm)	6	20.69	**63**	**53.3**
Medium-small (40–60 mm)	34	**68.97**	25.9	46.6
Medium-large (60–80 mm)	**54**	10.34	7.4	–
Large (>80 mm)	6	–	3.7	–
Total	100	100	100	100

In summary, even though some expedient tools are recorded, the greatest maximization in the use of Cerro Largo Formation chert is remarkable. The small size of the tools, the use of a bipolar technique and the presence of resharpening flake-edges show a curated technological strategy on this lithic raw material for these

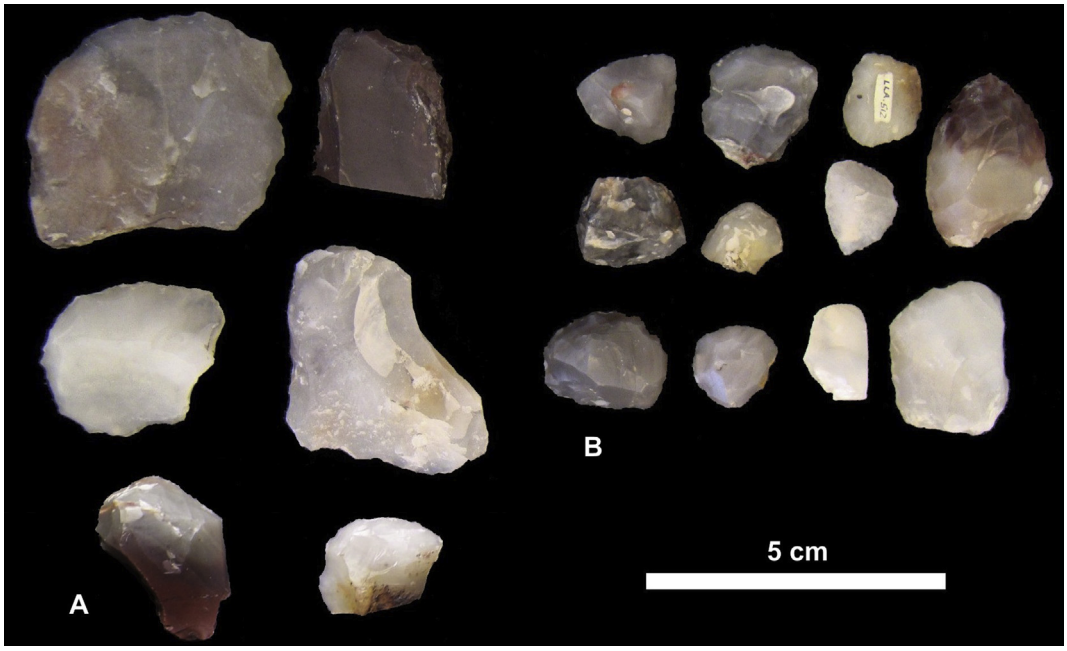

Fig. 10. End scraper sizes and shapes: A- Empalme Querandíes 1 and Laguna La Barrancosa 2; B- Laguna La Larga.

sites away from the hills. Possibly, the acquisition of this rock would have been made through logistical trips to the sources during the annual mobility of hunter-gatherer societies or in the course of the participation in extensive exchange networks due to the great distance between the lagoons and the quarry workshops identified in the Tandilia Hill System.

6. Final remarks

The techno-morphological studies of chert artifacts from quarries and workshops allow us to interpret how the procurement, exploitation, and use of lithic resources (the initial stages of technological organization) were carried out, as well as what kind of access to resources existed, which were their acquisition costs, which social and symbolic factors were involved, and how rocks move from procurement sources to other sites within the settlement system (Binford, 1979; Torrence, 1986; Nelson, 1991; Andrefsky, 1994; Beck et al., 2002; Bayón and Flegenheimer, 2004; Topping, 2011; Messineo and Barros, 2014; among others). It is proposed that Cerro Largo Formation chert had been transported from this workshop to other sites in the form of different kinds of partially and/or totally decorticated cores, large flakes, and possibly tools. Unmodified, good quality chert nodule transportation would have been frequent, as chert outcrops in hills. Moreover, in Empalme Querandíes 1 and Laguna La Barrancosa 2, several sizes of nodules and partially decorticated cores were recorded, confirming this kind of transportation (Messineo, 2011; Messineo et al., 2013).

As the distance increased between the sources of raw materials and archaeological sites located on the plain, the hunter-gatherer groups would have applied different strategies in order to access available raw materials. When the sources of raw materials were located at short distances from camps, such as Empalme Querandíes 1 and Laguna La Barrancosa 2, the acquisition of resources could have been made directly, while performing other subsistence task (embedded strategy, *sensu* Binford, 1979), or through a logistic mobility (direct strategies, *sensu* Gould and Saggers, 1985). In this sense, the presence of complete *chaînes opérotoires* in these archaeological sites close to the hills could be related to the direct access to the outcrops and the easy acquisition of chert in quarries. Also, we recorded an exiguous investment of labor in the production of tools, a poor standardization and transformation of the blanks (except in the manufacture of projectile points) and a high frequency of flakes utilized to manufacture diverse kind of tools, although some flakes with natural edges were used without being retouched (Messineo, 2011; Pal, 2012; Colantonio, 2013; Messineo and Barros, 2014).

When the distance between sites increases, the acquisition of the raw material could require a more complex organization, involving special trips through logistical mobility to the outcrops, because they implicated different searching and procurement costs (see Beck et al., 2002), or participation in extensive exchange networks (Ericson, 1984; Gould and Saggers, 1985). When considering non-local rocks (40 km or more from the outcrops) in Laguna La Larga and Laguna Seca 2 sites, Cerro Largo Formation chert has a secondary importance, with low percentages. In these assemblages, a higher proportion of standardized, small and shaped tools such as end scrapers (Fig. 10; Tables 2 and 3), exhausted cores, and small-sized flakes with no cortex were associated with raw material maximization. The acquisition of this lithic raw material would have been done by specific trips or by social exchange and interaction networks with others groups, where the distribution of utility and prestige goods was promoted. This kind of acquisition could be related with the heterogenic distribution of the lithic resources in the Humid Pampas sub-region.

Through the study of a particular rock as chert, an attempt has been made to deepen technological analysis of the different acquisition areas, the way in which this stone was transported to different environments of the Humid Pampas sub-region, and how the *chaînes opérotoires* developed in those sites. In this sense, this research was focused to interpret the role of Cerro Largo Formation chert in the technological organization of human groups and the strategies of resource acquisition and mobility in a regional scale. Finally, something more complex to interpret is the technological traditions that can be observed through the way the stone had been exploited and manufactured (Edmonds, 1999). Technologies in a society may also been related because they share the same actors, the same places, the same artifacts, the same materials, the same

sequences of gestures, or the same technological processes (Lemonnier, 1992). This work tried to interpret some of these statements, although more research must be done to have a more complete technological perspective.

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