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Study of siliceous outcrops of Meseta del Fresco, La Pampa, Argentina

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ABSTRACT

This paper introduces the results of the study of the silicifications from Meseta del Fresco (Fresco Formation), a vast source of chert in La Pampa province (Argentina), that was widely used by hunter–gatherer groups from the Pampas as a source of raw material. Petrographic analysis of different thin sections, both from geological samples from different parts of the unit, as well as from cultural material associated with the outcrops, was performed. The objective that guided these studies was to develop a detailed description of the type of siliceous replacement upon the prior rock (limestone) and from the filling of its cavities.

The results obtained let us inquire about the nature and origin of silicification, about the diversity depending on the location in the profile of the carbonate rock replaced during the diagenetic process, and about the extent to which this process affected the Fresco Formation at various points sampled. From an archaeological perspective, the analysis constitutes an advance in the study of lithic resources procurement behaviors developed by hunter–gatherer societies in the past because: 1) a database about the characteristics and variations of the silicification present in the outcrop was generated, as a tool to compare the archaeological samples from different sites, 2) different degrees of rock silicification that could favor its aptitude for knapping, were tested. This could have motivated preferential selection for making lithic artifacts. The archaeological information recorded in different sites on the eastern and western slopes of Meseta del Fresco is quantified in order to show the differential use of both areas.

1. Introduction

Rocks employed to manufacture lithic artifacts allow us to characterize their mineralogical composition through petrographic analysis or chemical studies, making possible to correlate the raw material selected with a specific outcrop and determine its place of origin. Because of this, they are considered as some of the best evidence for understanding the home range of the hunter–gatherer groups (Binford, 1979; Kelly, 1992; Amick, 1994; Franco and Borrero, 1999; Mangado, 2006).

The analysis of the lithic raw material sources has been for decades an issue of interest and part of the research agenda in the Archeology of the Pampas (Lozano, 1991; Flegenheimer, 1991; Berón et al., 1995; Flegenheimer et al., 1996, 1999; Ormazábal, 1999; Berón and Curtoni, 2002; Barros and Messineo, 2004; Berón, 2004, 2006; Curtoni et al., 2004; Messineo et al., 2004, 2009; Catella et al., 2010; Colombo, 2011, 2013). The developed research has been intended, on the one hand, to set the spatial location of the different lithic resources used in the past, and on the other hand, to the intrinsic study of specific sources of supply. This work is aligned within the latter research trend.

Archaeological investigations in Meseta del Fresco began a decade ago, when it was noted as the place of origin of a siliceous type of rock (chert) that was recurrently recorded in the archaeological assemblages of different sites of the West Pampa, Argentina. Since the first works performed in the site, it was noticed that the exposed rocks had a significant variability not only in relation to color, but also in degree of silicification (Berón and Curtoni, 2002; Berón, 2004, 2006; Curtoni et al., 2004).

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The field work developed in different sectors of Meseta del Fresco made it possible to identify specific locations of actual use of the quarries (South Foothill and West slope) and distinguish them from those in which the rock has less favorable conditions for the production of chipped stone tools (North Foothill and East slope). Topographic variations associated with the characteristics of the archaeological material were also recorded. Three different altitudinal sectors were differentiated, taking into account the topographic variations, and the presence of archaeological materials with different characteristics (Fig. 1). These sectors are:

a) Summit: the top of this landform was prospected in its southern and northern foothills. Large chert nodules, siliceous cores and numerous artifacts were identified, as well as the presence of large siliceous blocks fragmented by weathering action. In the northern sector (Aguada del Chinchín), extensive veins of siliceous chert were observed, but flaked material is scarce or difficult to differentiate because of the effects of weathering.
b) Medium or slope sector: the northern foothills and eastern slopes have steep walls, while the southern ridge has a smooth and extended slope. Throughout the latter, lithic artifact distributions were recorded, with alternating situations of dense concentrations and dispersion. These concentrations would constitute true workshops. The lithic artifacts found here are characterized by smaller sizes than the upper ones, and have strong patina and evidence of transport and bearing.
c) Base: is a sedimentary plain with small erosion gullies produced by rains. On the western slope, workshops and multiple activities surface sites were detected. In one of them, Memoria del Fresco site, abundant bifacial base forms (blanks) were recovered at different stages of formation. On the west side, abundant springs are present (Aguada del Fresco, Aguada del Toro and Aguada de los Caballos) but the density and artifact variability is significantly lower.

The general goal of this paper is to study the raw material of Meseta del Fresco and analyze their exploitation throughout time and space. Otherwise, the specific goal is to develop a detailed description of the type of siliceous replacement upon the prior rock (limestone) and the form of filling its cavities. This information let us inquire about the nature, diversity, and origin of silicification, and also about the extent to which this process affected the Fresco Formation at the various points sampled. Moreover, from an archaeological perspective, thin section analysis can determine whether certain degrees of rock silicifications favor aptitude for knapping, and also constitute a data base to compare the archaeological samples from different sites located in the Pampas, as well as neighboring regions.

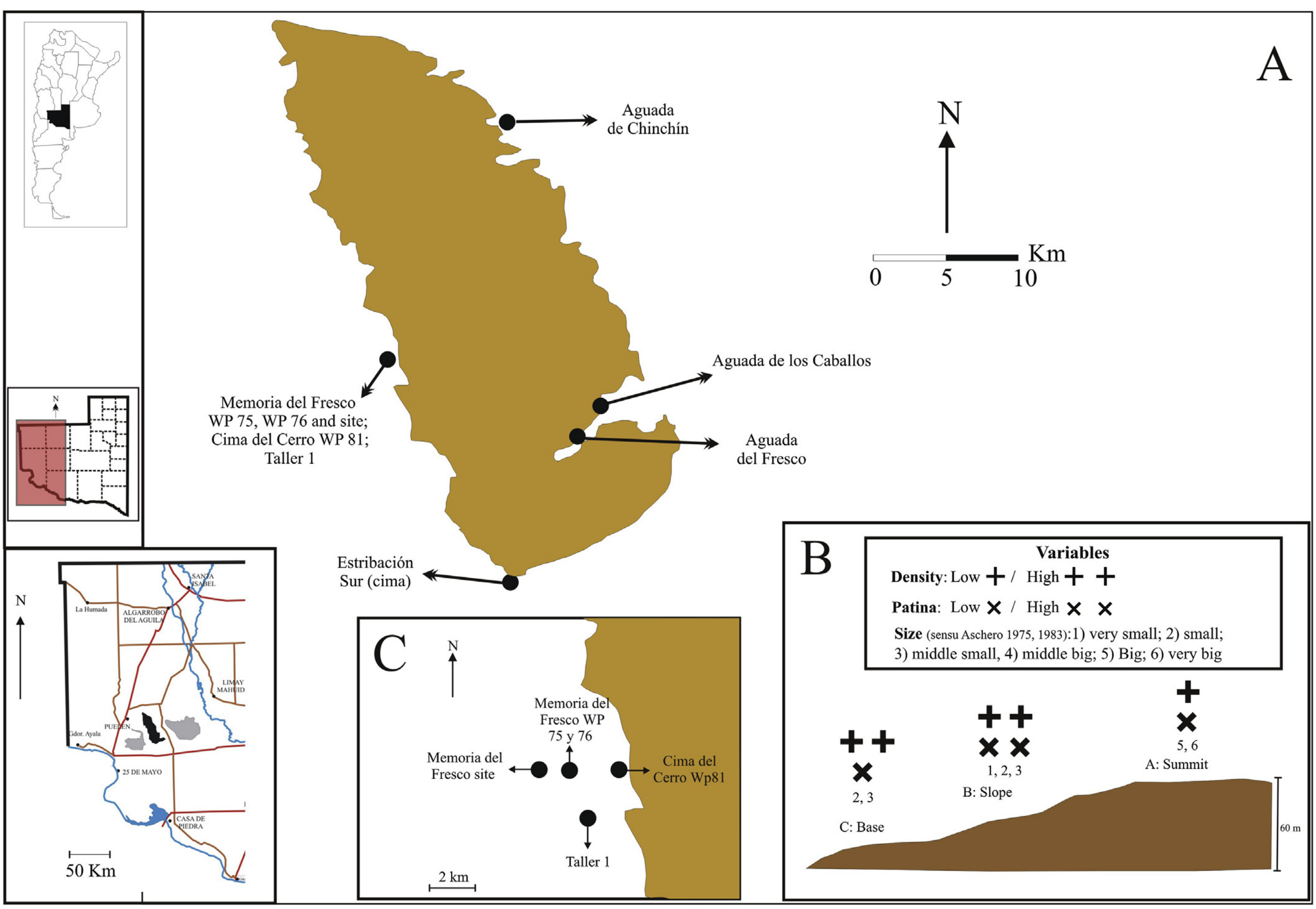

Fig. 1. A) Location of Meseta del Fresco and locations where samples were collected for petrographic thin sections; B) Details of the location of Taller 1, Memoria del Fresco site, Memoria del Fresco WP 75 and 76, and Cima delCerro WP 81; C) Cross-section of plateau indicating different altitudinal sectors, and features of lithic artifacts recorded (modified from Berón y Curtoni 2002).

2. Meseta del Fresco regional setting

Meseta del Fresco is a plateau of ~42 km long and ~13 km wide. It is located in the southwest of La Pampa province, in the vicinity of Puelén village (Department Puelén, 37° 25′ 304″ S; 67° 22 ′ 343″ W) (see Fig. 1).

From the physiographic point of view, the area corresponds to the Western Region, subregion "of the terraces and paleo river beds with volcanics boulders" (INTA, 1980). It is characterized by a semiarid climate, with limited rainfall. With regard to the topography, the surrounding landscape is a broad sedimentary plain, so the plateau stands out visually, even when its height does not exceed 60 m from the surrounding environment. Phytogeographically, is located in the Monte province (Cabrera, 1976). According to INTA (1980), the area is covered by two main vegetation types of low scrublands, open and evergreen. The main species are creosote bush (*Larrea divaricata*), thyme (*Acantholippiaseriphioides*), fine flechilla (*Stipatenuis*) and coirón (*Stipaspeciosa*).

In terms of geomorphology, this subregion is well defined. Their presence is closely linked with the history of the Colorado River, whose action left its mark on the landscape, leading to what Calmels (1996) called the "Paleoabanico del río Colorado", characterized by an extensive plain with regional slope in the northwest - southeast direction. Paleo river beds are recognized as depressed forms, filled with eolian sand, while emerging landforms are represented by fluvial terraces and elongated plateaus. In the case of Meseta del Fresco, its origin was the presence of a calm water pond, where diagenetic processes lead to the formation of a body of hard rocks (silicified limestone), which preserved it from the local erosion processes. For this reason, Meseta del Fresco stands as a high visibility landform.

The major sedimentary materials that compose Meseta del Fresco are silicified oolitic limestone crusts. Drainage receptacles in this area are two saltpeter beds surrounding the plateau: La Perra and Salina Grande or Gran Salitral (INTA, 1980; pp. 136–140).

3. Archaeological background

From the archaeological point of view, Meseta del Fresco is an important source of silicified limestone (chert), frequently present in the archaeological record of the West Pampa and also in a macro-regional scale including Wet Pampas subregion. Through thin sections conducted in archaeological samples and compared with geological ones presented in this paper, the use of siliceous limestone from Meseta del Fresco in different parts of the province of La Pampa was determined. There are 22 archaeological samples that include material from different sites: Manantial Naicó and Laguna de Paisani (Center-east area); Médanos de Costilla, San Sixto and La Cascada (Valles Transversales area), La Chola (Bajos sin Salida area) and the site 1 of Tapera Moreira archaeological locality (top of Lower Component and Upper Component; Curacó area; Fig. 2). Analysis of these data allowed us to determine that 18 of the samples correspond effectively to siliceous limestone coming from Meseta del Fresco. The remaining four samples (two from Manantial Naicó and two from Tapera Moreira) differ in their characterization from geological thin sections, although they are siliceous limestone. However, although it was not possible to determine the exact place of origin, they may come from some sector of Meseta del Fresco that was not sampled.

Regarding the archaeological record of this raw material, site 1 of Tapera Moreira locality recorded a frequency of ~5% in each cultural component, with a lithic assemblages consisting mainly of debris (>90%), and to a lesser extent tools and cores. The latter are scarce, most are complete, and have small to large sizes (Berón, 2004). In the case of tools, bifaces, projectile points, scrapers and knives made with this rock were identified. Throughout all the cultural sequence, flakes without cortex and small to medium-small sizes predominate. The ratio debitage flakes/tools increases dramatically in the Middle and Upper Components, which may indicate that for this period (ca. 2100–500 BP) human groups could have been producing tools that were not discarded at the site. The low frequency of cores, as well as elements with cortex, indicate that rocks were transported with an advanced degree of knapping (Berón, 2004).

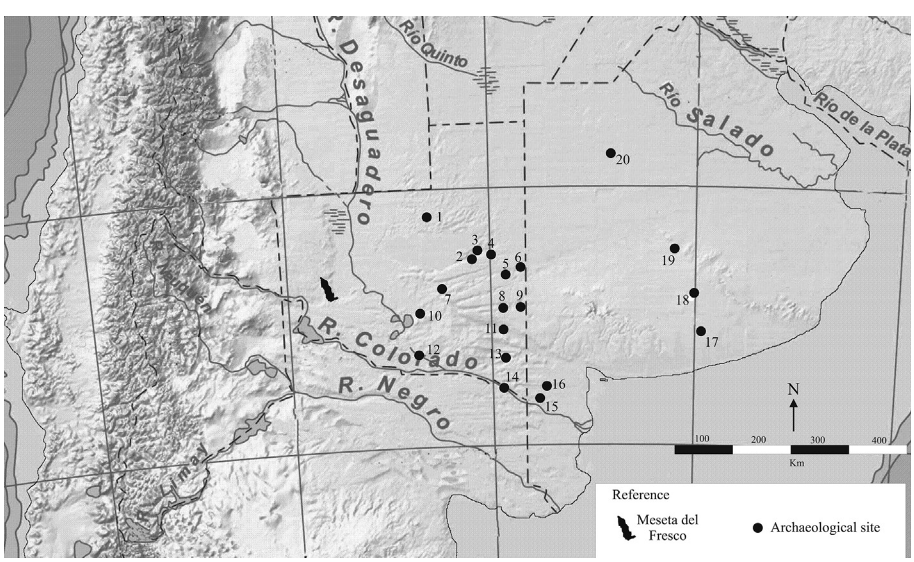

Fig. 2. Map showing the distribution of artifacts possibly made of siliceous chert from Meseta del Fresco, in different sites and archaeological localities of the Pampean Region: (1) Don Isidoro, (2) Laguna de Paisani, (3) Manantial Naicó, (4) Parque Luro, (5) La Cascada, (6) Médanos de Costilla, (7) El Carancho, (8) La Tigra, (9) San Sixto and Bajo de Marcelino, (10) Lihué Calel archaeological locality, (11) La Colorada Grande, (12) Tapera Moreira archaeological locality, (13) La Chola, (14) Médano La Enriqueta, (15) El Puma 3, (16) Caldén Guazú, (17) Las Brusquillas 1 and 3, (18) Laguna La Barrancosa 2, (19) Arroyo Tapalqué 1, (20) Laguna de los Pampas.

On those sites that integrate the Bajos sin Salida area (i.e. La Chola, Médano La Enriqueta, La Colorada Grande, see Fig. 2), the rock has a lower frequency than 10% and is represented mainly by internal small size flakes. Tools recovered consist of two compound artifacts, scraper, biface, and flake (one of each) with marginal retouch. According to the characteristics of these artifacts, it is considered that the activities preformed with this raw material, were mainly oriented to the maintenance of tools.

Among the sites located in the Valles Transversales area (see Fig. 2), the rock is represented in different forms. In La Tigra site, siliceous limestone constitutes 30% of the lithic assemblage recovered, while in San Sixto, La Cascada, and Médanos de Costilla its frequency is ~10%, and in Bajo de Marcelino site around 1%. In most sites, cores were recovered, although their frequency is very low (one per site), indicating that it was unusual that the rock was transported in this way. Prevailing among the tools are scrapers and flakes with marginal retouch. A high frequency of internal flakes (>85%), most of which are small to medium-small size, is observed at all sites. Activities were focused predominantly on maintaining tools, and only occasionally on manufacturing.

In those sites located in the Central-east area (see Fig. 2), differences in the frequencies of this raw material are also recorded. In Laguna Paisani and Laguna del Fondo it represents ~50%, while in Manantial Naicó its frequency is below 20%. Most assemblages are composed of internal and small size flakes. The cores come almost exclusively from Laguna Paisani, with prevalence of the amorphous type and medium-small size. Twelve types of tools were identified. Of them, 40% are informal (sensu Andrefsky, 1994). Between formals, there are bifaces, projectile points, knives, compound artifacts, and scrapers, among others. Most of them are broken, showing that they were discarded at the end of their useful life. According to the frequencies and characteristics of the artifacts, in Manantial Naicó, the activities were primarily related to the maintenance of tools, while in the other two sites, it is likely they were manufactured (Carrera Aizpitarte, 2014).

On the other hand, in Chenque I (see Fig. 2), a hunter–gatherers cemetery, artifacts were also recovered which raw material can be macroscopically identified as siliceous limestone from Meseta del Fresco. Among the recovered items, there are small cores, tools and debris. Among the latter, complete flakes of small size and medium-normal modules prevail. Most of them are angular type, and to a lesser extent bipolar and bifacial thinning. The tools consist of end scrapers, side scrapers (the so-called *raederas*), burins, perforators, and projectile points (Velardez, 2005, in press). These latter are characterized by being inserted in some skeletal remains. For example, in burial 17, dated to 990 ± 60 BP and also in burial 19, dated to 720 ± 20 BP, a projectile point inserted in the anterior side of a dorsal vertebra and in the hip zone, respectively, were recovered (Berón, 2010, 2013). It is considered that in this site, rock was used intensively and the activities performed were oriented to the production of basic shapes and tool manufacture. However, it is possible that some artifacts entered the site at an advanced manufacturing degree (Velardez, 2005, in press).

In the province of Buenos Aires (see Fig. 2), the siliceous limestone has been identified in different places, always with a small number of elements. In El Puma 3 site, only one flake and two tools on flakes were recovered. The latter are an edge in asymmetric bezel and a flake with complementary traces (Santos Valero, 2013). In the Interserrana area, two flakes were detected, one at the Las Brusquillas 2 site (dated to 1795 ± 88 BP) and the other at the Upper Levels of Las Brusquillas 1 (Massigoge, 2011, 2012). In Laguna La Barrancosa 2, four tools (three end scrapers and edge in asymmetric bezel) were identified. In Arroyo Tapalqué 1, in addition to this latter type of tool, a fractured flake was also recovered (Messineo, 2008). In surface collections from General Lamadrid there were identified a limited number of internal flakes and a projectile point fragment (Kaufmann, 2013 personal communication). The characteristics of the artifacts recovered in this subregion are those expected for raw material coming from long distance sources, which are usually obtained indirectly and with an advanced manufacturing degree (i.e. preforms or manufactured tools).

In a broad sense, the use of silicified limestones begins in the Pampas at the Pleistocene–Holocene transition because they were employed for making fishtail projectile points and other bifacial artifacts (Flegenheimer et al., 2003; Armentano et al., 2007; Martínez and Gutiérrez, 2011). Through analyzing the provenance of this raw material, two possible sources of supply were considered: Meseta del Fresco or Queguay Formation (Uruguay). However, based on petrographic analyses of thin sections, in these cases it was linked to the Queguay Formation by the presence of carophyte (Flegenheimer et al., 2003).

4. Geological background

4.1. Origin of the plateau

Meseta del Fresco consists of Eocene age sediments, so it was initially considered as an exponent of the Vaca Mahuida Formation. This formation was defined in La Rinconada, Río Negro province, by Uliana and Camacho (1975). These authors conclude that, in its type area, the sequence represents the passage of a marine environment to another of freshwater and, according to marine invertebrates found, they establish its chronology in the middle or superior Eocene. Later studies recognized lithological and structural differences between the outcrops of Meseta del Fresco and the type locality of the Vaca Mahuida Formation, which led to the incorporation of the first in a new lithologic unit, the Fresco Formation (Melchor and Casadío, 1999).

The paleoenvironmental interpretations for this unit refer, on the one hand to a depositional tidal environment (Rubin, 1990), and on the other hand, to a lacustrine environment (Wichmann, 1928; Melchor et al., 1992). However, Pos-Rocaneses strata (Sobral, 1942) and Vaca Mahuida Formation (Uliana and Camacho, 1975) with which it was previously grouped were described as sediments deposited in coastal marine environments. Melchor et al. (1992) consider that the strata of the El Fresco Formation represent the passage of a marine environment to fresh water. According to the authors, the sediments were deposited in a depressed area of about 700 km^2, occupied by a lake of fresh water, which would have suffered significant fluctuations in its coastline position.

Although the general framework appears to have been of lacustrine sedimentation, a poorly preserved ostracod association and a specimen of foraminifera, recovered in Lomas Cochi-Coén's profile, indicate a marine phase. As a result, Melchor and Casadío (1999) postulate the hypothesis of a probable marine influence at the onset of sedimentation of this unit in the area.

4.2. Stratigraphy and lithological properties

In general, the sediments of the plateau are composed by an alternation of banks of pelites, greenish to pinkish, with abundant interbedded pyroclastic rocks (chonite, tuffs, cinerite and tuffites), limestone (often silicified), marls, and subordinate sandstones. The calcareous strata often contain poorly preserved, very small remains of bivalves and crustaceans (Linares et al., 1980; Melchor and Casadío, 1999). "Macroscopically, the chert that comes from the Fresco Plateau presents features that clearly indicate its origin, as it presents areas of limestone not silicified, with oolites and/or drusitas, very typical of this formation" (Llambías 2000 personal communication, in Berón and Curtoni, 2002; pp. 175).

Its stratigraphy was extensively analyzed by Melchor et al. (1992) who carried out detailed profiles from which they identified four shallowing units (packages of relatively concordant strata bounded by maximum flooding surfaces) and six sedimentary lithofacies. Among the latter is emphasized the Vth, associated with chert. It is characterized by its silicification and consists of: 1) oolitic "grainstone" 2) bioclastic "grainstone", 3) calcareous arenite and 4) peloidal "grainstone" with scattered silicified gastropods. This lithofacies is present in all the shallowing units, but is only associated with chert in units 2 and 4 (roof of the Plateau: Melchor et al., 1992). According to Melchor and Casadío (1999), the degree of silicification of peloidal limestone from the top unit is areally variable, and can achieve relatively low local values, for example in the extreme northwest of Meseta del Fresco (Puesto Salitral Blanco).

Moreover, in a relieved profile in the area known as "Mancha Blanca" (south end of the plateau), it was observed that: "(…) In surface emerge 0.40 m of light olive green flint with abundant presence of manganese dendrites, this "crust" covers a silicified limestone mantle of 1–1.2 m thick, followed down one green opal horizon of 0.2–0.4 m thick that overlies a layer of about 6 m thick pelites with a high proportion of gypsum dry earthy look to green crystalline and high carbonate participation" (Dalponte et al., 2002; pp. 12.).

5. Diagenesis of silica process

For a better understanding of the silica diagenesis held in this quarry, the replacement processes that regularly occur in this type of formations are described. The term diagenesis is used to indicate the geological processes from which sediments (unconsolidated aggregate) become a sedimentary rock. These processes begin after the deposition has been produced and include compaction, fluid loss, depositional porosity reduction, cementation, lithification and recrystalinizaction of some minerals (Limarino, 2011). According to Hesse (1989), "silica diagenesis" refers to the phases of transformation between different solid forms of silica (opal A, opal CT). They occur in siliceous sediments during stages of shallow to intermediate burial, but also involve the silicification of originally non siliceous sediments (for example, carbonated rocks).

Through diagenesis, the amorphous opal of biogenic components (opal A) becomes a component of disordered and interbedded crystalline structure formed of small crystals, lamellar or spherulitic (opal CT). By the same process, opal CT becomes micro quartz or chalcedony, producing obliteration of the original organic structures (Hesse, 1989; Spalletti, 2009). All these transformations cause a significant decrease of the porosity from 90% to less than 10% without the need for compaction (Spalletti, 2009).

Opal A is concentrated by radiolarians, diatoms, and siliceous sponges. Besides being present in marine environments, chemical sedimentary siliceous products can be found as: A) biogenic accumulations (diatoms) in lacustrine environments, B) chemical precipitation in highly alkaline lakes; C) chemical precipitation (bacterial) in continental hot springs; and D) silcretes (Spalletti, 2009).

5.1. Silicification process

The silicification is a diagenetic phenomenon developed in a wide variety of non-siliceous sediments, occurring in a range between penetrating and minority (Hesse, 1989; Thiry and Ribet, 1999). This process involves the dissolution of the previous rock (limestone, dolomite, gypsum, clay, etc.) and precipitation of the silica minerals (usually quartz), resulting is the origin of silicate rocks with nodules lenticular or irregular bodies morphology that appear included in the replaced rocks (Hesse, 1989; Bustillo et al., 2010). The silicification can occur in different circumstances: in a shallow burial during sedimentation; in connection with bioturbation and bacterial metabolism, or delayed, during recrystallization of carbonate (Thiry and Ribet, 1999).

Frequently, silicification is conducted on a microscale, by replacement, allowing many of the original rock characteristics to be preserved, allowing recognition of fossils, nodules and pseudoclasts in the silicified matrix (Thiry and Ribet, 1999; Bustillo et al., 2010). The perfect preservation of the structures indicates that the precipitation of silica and calcite dissolution occurred simultaneously (Thiry and Ribet, 1999). As a result the siliceous rock acquires, from the previous rock, a record serving for identification when it appears outside the context in which it was formed (Bustillo et al., 2010).

There are two main types of silicification: filling of the cavities, and replacement of the host rock by microcrystalline quartz. During silicification, cavities play an important role, as the body fluid allows silica precipitation, as well as transport of the dissolved rock. As silica has low solubility in surface water, a high flow is required to continuously renew the mineral precipitated out of solution. That is why the porosity is important, and there is a strong relationship between the cavities and silicification. The latter is more intense in the channels and connecting sections, which are the places where the flow is higher (Ribet and Thiry, 1990; Thiry and Ribet, 1999).

The silicification can occur by precipitation in cavities (packing) or by replacement of host rock. In the first case, the quartz accumulated in cavities has a specific distribution which shows high to low crystallinity of the precipitated phases. In this sense, the inner edge is filled by microcrystalline quartz, which is followed by small quartz in palisades, concluding in the center with euhedral crystals in mosaic (Ribet and Thiry, 1990; Thiry and Ribet, 1999).

The filling of the cavities is a phenomenon that occurs by direct precipitation from solution. Only occasionally is opal replacement by another phase, mainly chalcedony, observed. If silicification is less limited, single or multiple banding is observed. Noted are:

a) Botryoidal tapes or bands. Quartz crystals have the appearance of flame and wavy extinction.
b) Uniform bands of quartz in palisade and chalcedony and megaquartz inward. These phases of quartz grow from solution.
c) Band quartz in palisade and sparite in the center of the cavity.

The replacement of the host rock occurs only if the quartz crystalinization induces dissolution of the rock. In this sense, the growth of the quartz crystals exerts pressure on increasing the solubility of calcite. This process involves a silica supplement from water flow. Moreover, water is also responsible for transporting the dissolved material.

The transfer of chemical species between the cavities and the front replacement proceeds through the diffusion of the fluid from the joints of the crystals. Thus, the extent of diffusion limits the extent of replacement: to a greater distance between body cavities and replacement front, the diffusion gradient is minor, and replacement is slowed until it finally stops (Thiry and Ribet, 1999).

5.2. Silica factories

At least seven silica factories have been recognized, some of which have as precursors opal A and/or opal CT. These phases, however, generally are not preserved and their original presence is difficult to prove. Factories can be divided into two groups: equigranular type and fibrous type (Hesse, 1989). The first group includes microcrystalline quartz and megaquartz, with crystals of 5–20 microns in diameter, cryptocrystalline when observed under the microscope. The second consists of mosaic crystals (size range 20–2000 microns), which show a progressive increase in their sizes from the margins to the center. It is a typical cement factory, although not exclusively.

Factories comprise fibrous chalcedony or quartz chalcedony, quartzine, lutecite, zebraic chalcedony, and micro flaming quartz. Chalcedonic quartz is the most abundant fibrous variety. Mineral fiber elongation is perpendicular to the crystallographic C -axis. The fibers grow from a point and are distributed radially. This pattern is characteristic of chalcedony that occurs as cement filler. The chalcedonic quartz is followed by megaquartz. The grain size is increased through the central pore, and locally by spherulitic quartz. For the quartzine, the fiber elongation is parallel to the C crystallographic axis. This is common in chert nodules replacing the initial evaporites. Lutecite, moreover, is intermediate between chalcedonic quartz and quartzine. Fibers have an inclination of 30° to the C axis. The zebraic chalcedony is commonly associated with chert replacing evaporites, and is characterized by a banded extinction pattern when viewed with cross-polarized lights. Micro flaming quartz is characterized by showing wavy extinction. This is intermediate between equigranular fibrous types.

With respect to the origin of the above factories, only chalcedonic quartz stems from precipitation of silicification cavities. Lutecite is the only factory generated exclusively by replacement, although zebraic chalcedony and quartzine are also predominant results of this silicification process (Hesse, 1989).

6. Material and methods

Optical microscopy studies are a fundamental technique for the recognition of minerals and other components, as well as for the geological characterization of the rocks. Their usefulness is based, firstly, on the possibility of identifying the mineralogical composition, organic content, and diagenetic depositional features, among others, and on the other hand, because they enable us to carry out studies of structure and texture. In these analyses, the identification of minerals is performed through their optical properties, which are related to the interaction of visible light with the substances. They are determined precisely by the chemical composition and crystal structure of substances. Thus, each mineral has specific optical characteristics that allow identification (Jiménez and Velilla, 2004).

In order to characterize the rocks of Meseta del Fresco from a compositional-mineralogical point of view, samples from different points were collected (see Fig. 1). A total of 23 petrographic thin sections were conducted corresponding to the following sampling sites: one of the Aguada del Chinchín at the north end; four in each areas sampled of the eastern side: Aguada de los Caballos and Aguada del Fresco; and four in top of Estribación Sur. In the case of the western slope, with the greatest archaeological density, the points sampled are Cima del Cerro WP 81 (2 samples), Memoria del Fresco WP 76 (2 samples) and Memoria del Fresco WP 75 (6 samples) (Fig. 3). In Table 1, the macroscopic characteristics of each of the rocks on which the thin sections were made are detailed.

Regarding the archaeological record, materials from Estribación Sur, in the south end of the plateau, Aguada de los Caballos and Aguada del Fresco, on the eastern slope, as well as Memoria del Fresco in western side, were analyzed. The results achieved by Curtoni et al. (2004) in Taller 1 are also included. The latter site is a lithic workshop related to the exploitation of silicified limestone from Meseta del Fresco, located ~200 m from Memoria del Fresco (see Fig. 1).

The artifact analysis was performed from a techno-morphological perspective, as proposed by Aschero (1975, 1983) and Aschero and Hocsman (2004). For a better understanding of the data presented, the size categories used are: very small (up to 1 cm^2), small (1–4 cm^2), medium-small (4–9 cm^2), medium-big (9–16 cm^2), big (16–36 cm^2) and very big (more of 36 cm^2).

In the case of Taller I, the original designation is maintained. They define the following categories: “artifacts” include complete and broken flakes; “microflake” refers to flakes smaller than 1 cm^2 and “undifferentiated” include the unmodified stones, as well as all items that cannot be assigned to another categories or typological group.

7. Results

7.1. Aguada del Chinchín

The matrix presents a crypto to microcrystalline silicification, where the previous rock texture cannot be seen. There is a greater representation of the sectors with spherulitic chalcedony and meso-crystalline quartz, the latter mostly fibrous. Sparitic calcite precipitation is also observed. The rock is classified as a silicified limestone, which is opalized to a chert (Fig. 4).

7.2. Aguada de los Caballos

In the thin sections, the matrix has cryptocrystalline silicification and the previous texture can be seen. In the same peloids, components and skeletal fragments can be recognized (which could correspond to ostracod shells, broken shells and spicules), replaced by cryptocrystalline silica and micro to mesocrystalline respectively. The matrix could correspond to a pelmicrite or pelbiomicrite (N°1), as well as a pelmicrite or intrapelmicrite (N° 2 and N° 3). With respect to the cavities, both in them and in the veins, replacement is quartz, micro to mesocrystalline (N°4), mesocrystalline (N°1) and meso to megacrystalline (N°2). In both cavities and in veins of sample N°3, the replacement occurs by mesocrystalline quartz that replaces opal. The precipitation of the latter is inferred by botryoidal bands which are then replaced by palisade quartz, and towards the center, mosaic quartz. With respect to classification, all the rocks are identified as silicified peloid limestones. However, N°1 is considered a pel-biomicrite while N°2 and N°3 are pel-intramicrite. All are opalized to chertified. N°4 is a silicified pelmicrite (Fig. 5).

7.3. Aguada del Fresco

Four thin sections were analyzed, where the matrix has cryptocrystalline replacement, even though the previous texture and fossils may be observed in some sectors. The N°1 could correspond to a biomicrite, while N°2 to a pelmicrite-biomicrite, both replaced by cryptocrystalline quartz. Moreover, in samples N°3 and N°4, the presence of sparitic calcite disseminated without replacement would involve the existence of dismicrite. It could be a pelmicrite-intramicrite-biomicrite replaced in parts by cryptocrystalline quartz, while others are dismicritizised. In the cavities, peloids are bordered by replacement (or cementing after dissolution) of tiled micro to mesocrystalline quartz. However, in N°3 and N°4, an opal outer remnant is present. With respect to classification, all rocks were identified as almost completely silicified limestones, although in sample N°1 the degree of silicification appears to be slightly higher (Fig. 6).

7.4. Top of Estribación Sur

In the thin sections made on rocks from the top of Estribación Sur, the matrix has cryptocrystalline silicification. In some cases the previous texture cannot be observed (N°1), while others do show it

Fig. 3. Sample artifacts from which petrographic thin sections were made.

(N°4). For samples N°2 and N°3, pinkish translucent bands indicate higher iron content, while in the whitish sectors the segregation of this mineral is present in the form of specks. As noted in the sample N°4 previous texture (peloids and bioclasts) is observed, which may correspond to a pelmicrite-biomicrite, where fossils are replaced by microcrystalline quartz, and peloids by cryptocrystalline quartz. The pores and cavities are scarce, and mesocrystalline quartz (N°1), microcrystalline quartz in mosaic (N°2), and mesocrystalline quartz mosaic plus fibrous chalcedony (N°3) precipitated inside them. Sample N°4 includes a vein with an outer remnant of opal, while towards the center palisade quartz and fibrous chalcedony are present. Moreover, there is microcrystalline quartz in mosaic around peloids. With respect to classification, all rocks were identified as silicified to opalized limestone (Fig. 7).

7.5. *Cima del Cerro WP 81*

In both thin sections, it can be observed that the matrix is partially silicified, and it is crypto to microcrystalline with possible allochemical components including intraclastic peloids and/or micrite matrix. With respect to the pores and cavities, palisade quartz precipitation is observed and inwardly megaquartz in the mosaic. Sparitic calcite precipitation is also noted. The rocks are classified as silicified limestone, opalized to chertified, with remnants of micrite without replacement (Fig. 8).

7.6. *Memoria del Fresco WP 76*

In the two selected rocks, the matrix has cryptocrystalline replacement in peloids, and in some sectors the previous texture is observed. They could correspond to a pelmicrite replaced by cryptocrystalline quartz (N°1) or crypto micro to mesocrystalline quartz (N°2). The latter sample could also account for a more mature silicification. Opal outer remnants may be observed in the cavities, and around peloids, micro to mesocrystalline quartz replacements in mosaic. In sample N°1, however, there is also the presence of fibrous chalcedony. Both rocks are classified as fully silicified limestones (Fig. 9).

7.7. *Memoria del Fresco WP 75*

The six thin sections made on rocks of this sampling point show that the matrix has full silicification and the original rock texture is not recognized. The replacement is given by microcrystalline quartz, although in samples N°1 and N°2, two types of areas may be distinguished, one where the replacement is crypto to microcrystalline with greater segregation of iron, and other with mesocrystalline quartz in fine mosaic.

In the cavities, samples N°1 and N°6, have crystallization of fibrous chalcedony, and in N°2 channel edge lattice quartz is observed, and toward the center, fibrous chalcedony. Samples N°3

Table 1
Macroscopic characteristics of hand samples from which petrographic thin sections were made.

Sector	N°	Type	Colour	Fracture	Brightness	Impurities	Classification	Observations
Aguada del Chinchín	1	Geological sample	Whitish light brown	Concoidal	Vitreous	Yes	Silicified limestone	–
Aguada de los Caballos	1	Flake	Dull gray with light spots	Concoidal	Vitreous	–	Silicified limestone	–
	2	Flake	Shiny gray with white impurities	Concoidal	Vitreous	Yes	Silicified limestone	–
	3	Core	Green	Concoidal	Vitreous	–	Silicified limestone	–
	4	Flake	Reddish gray	Concoidal	Vitreous	–	Silicified limestone	–
Aguada del Fresco	1	Core	Light gray	Concoidal	Vitreous	–	Silicified limestone	Cortex and white fissure
	2	Flake	Light gray with white spots	Concoidal	Vitreous	–	Silicified limestone	–
	3	Flake	Light gray	Concoidal	Vitreous	–	Silicified limestone	Gray greenish cortex
	4	Flake	Light gray with white spots	Concoidal	Vitreous	Yes	Silicified limestone	White dimpled outer layer
Estribación Sur, cima	1	Flake	Light gray with white spots	Concoidal	Vitreous	–	Silicified limestone	Highly silicified; Orange cortex
	2	Flake	Whitish light brown	Concoidal	Vitreous	–	Silicified limestone	Whitish gray cortex
	3	Flake	Translucent red with white spots	Concoidal	Vitreous	–	Silicified limestone	High degree of silicification
	4	Core	Translucent red with white spots	Concoidal	Vitreous	–	Silicified limestone	High degree of silicification
Cima del Cerro, WP 81	1	Flake	Orange light brown with white spots	Concoidal	Vitreous	Yes	Silicified limestone	Low degree of silicification
	2	Flake	Light brown to whitish gray	Concoidal	Vitreous	–	Silicified limestone	Low degree of silicification
Memoria del Fresco, WP 76	1	Flake	Redish	Concoidal	Vitreous	Yes	Silicified limestone	–
	2	Flake	White	Concoidal	Vitreous	–	Silicified limestone	–
Memoria del Fresco, WP 75	1	Flake	Translucent light brown	Concoidal	Vitreous	–	Silicified limestone	High degree of silicification
	2	Flake	Gray with white spots	Concoidal	Vitreous	–	Silicified limestone	High degree of silicification
	3	Flake	Gray with white spots	Concoidal	Vitreous	–	Silicified limestone	High degree of silicification
	4	Instrument	Light brown	Concoidal	Vitreous	Yes	Silicified limestone	High degree of silicification; White cortex
	5	Flake	Yellowish white	Concoidal	Vitreous	Yes	Silicified limestone	High degree of silicification
	6	Flake	Translucent light gray	Concoidal	Vitreous	–	Silicified limestone	High degree of silicification; White cortex

and N°5 have an outer vein whose edge seems opaline with fibrous chalcedony inward. In the center of one of the cavities, sparitic calcite precipitation is noted. Moreover, sample N°4 shows mosaic quartz in some sectors, micro, meso and even megacrystalline. According to the above features, all rocks have been classified as silicified to chertified limestone (Fig. 10).

7.8. Archaeological record

In the western slope, abundant evidence of use was identified, including workshops, that indicate intense exploitation of raw materials. There, a greater number of sites were recorded, represented by large surface concentrations of artifacts corresponding to the different stages of the lithic production system. In Taller I, two superficial squares of 1 m^2 sampling were performed, where all lithic items were recorded. The analysis indicates that there are differences in the density of lithic artifacts in each sample square: in sample 1, 4006 items/m^2 were registered, while in sample 2 the density is 2791 items/m^2 (Curtoni et al., 2004). The high artifact density often produces overlapping sites, making it difficult to establish their limits (Fig. 11). Something similar happens in the top of Estribación Sur, where in addition to the artifacts recorded on surface, different large blocks with evidence of edge banding have been identified (Fig. 12). Among the artifacts commonly recovered from the above described sites, the cores have different sizes and represent different stages of reduction, as well as flakes from the early stages of the lithic reduction sequence in the quarry. In Taller I the undifferentiated items predominate with 57%, followed by artifacts (28.6%), micro-flakes (13.1%), cores (0.5%) and tools (0.04%). Small (47.5%), very small (31.3%) and medium-small artifacts (14.3%) predominate. The medium-big to very big categories are also registered, but in lower frequency (6.7%). The amount of internal flakes is bigger than the externals. Moreover, in Memoria del Fresco, the presence of numerous bifaces and bifacial thinning flakes respectively, were identified. They correspond to the silicified limestone of very good quality, exposed in the plateau.

In the eastern slope, the archaeological record is less abundant and more circumscribed. In this sector the large concentrations of materials present on the western slope, are not observed. The samples recovered in Aguada de los Caballos and Aguada del Fresco are examples of this situations.

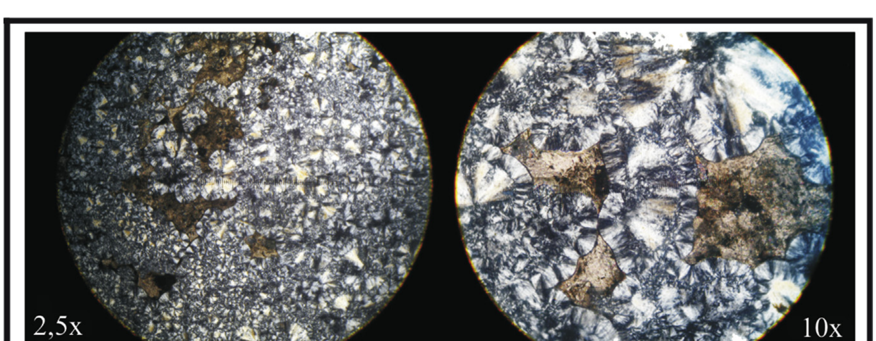

Fig. 4. Petrographic thin section with crossed nicols from Aguada del Chinchín.

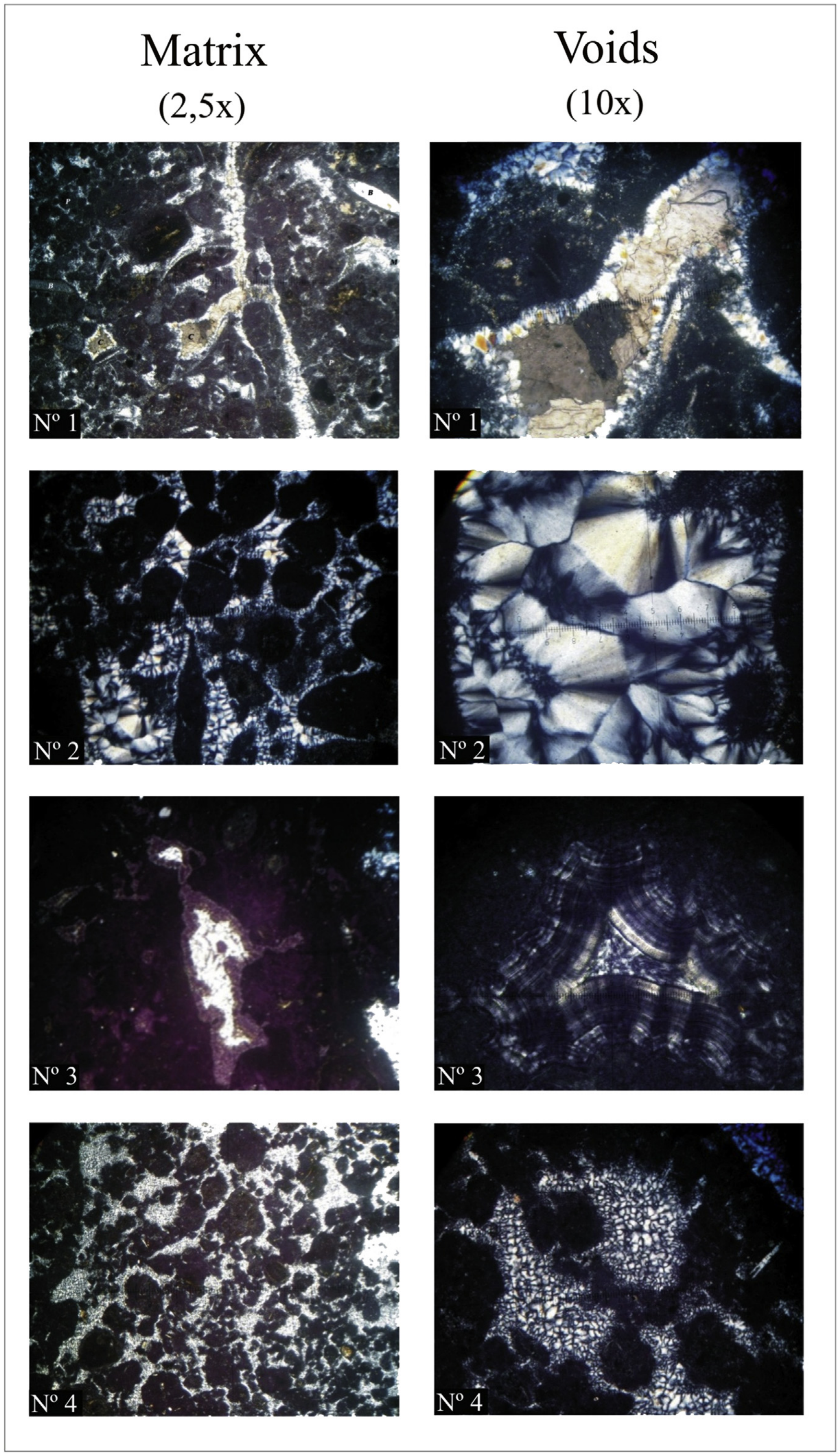

Fig. 5. Petrographic thin section with crossed nicols from Aguada de los Caballos.

The lithic assemblage recovered in Aguada de los Caballos is formed by 10 cores, 10 tools, and 216 debris. Most of the cores are complete ($n = 7$; 70%). Four elements have impurities and internal fissures, and only one has cortex. This could indicate the selection of more homogeneous rocks and/or with better quality for knapping. Also, four cores whose features indicate that they probably were discarded at the end of use-life were identified. Most of the complete cores are large ($n = 5$). The biggest is a white siliceous limestone block of 200 mm length, 70 mm width, and 76 mm thick. The negative flake scars indicates that the flakes obtained were medium-small to big sizes, and up to 5 mm thick.

Between the tools were registered artifacts made on siliceous limestone, as well as in other raw materials. The latter include a frontal end scraper and a projectile point made in silica, a

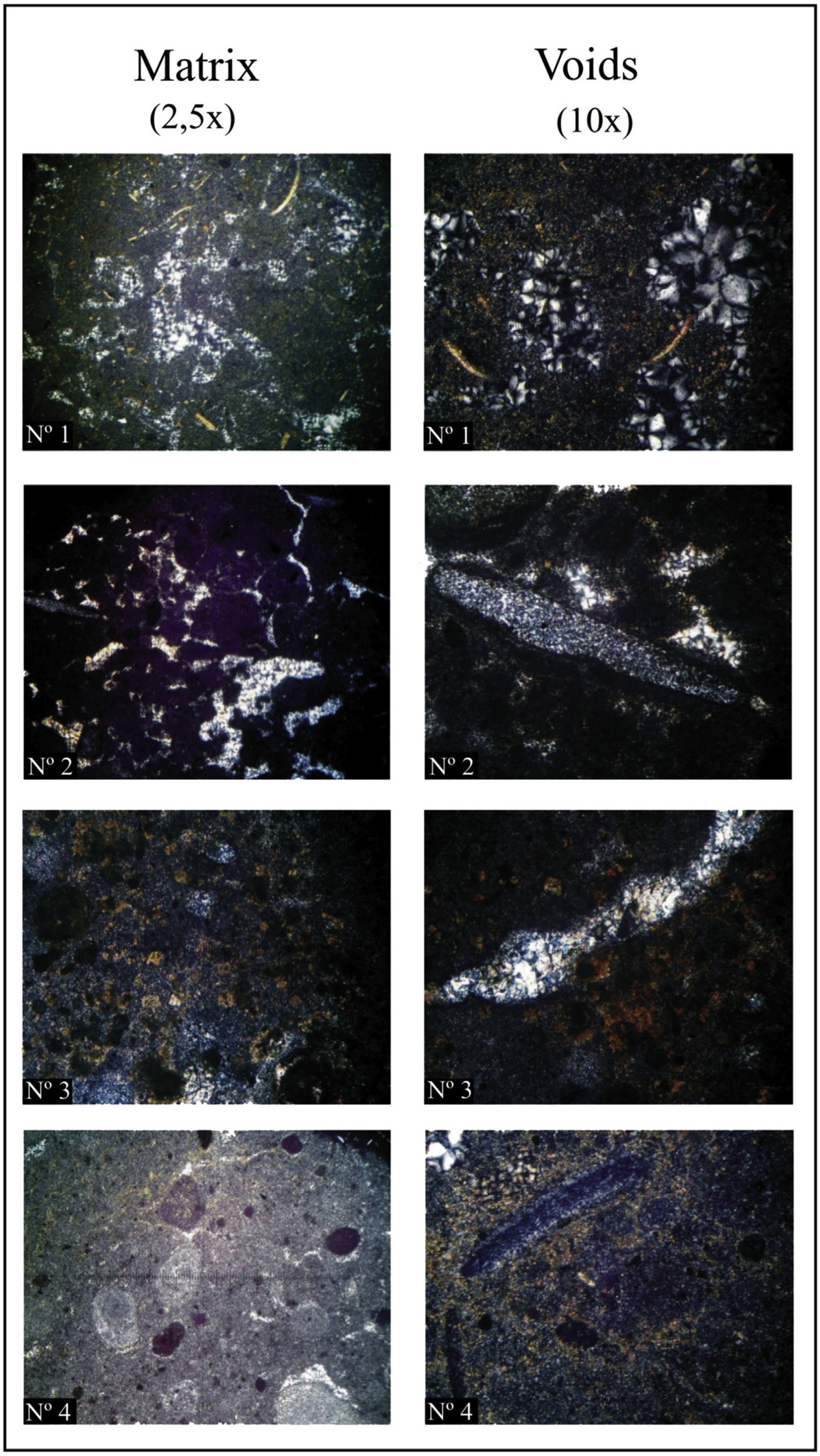

Fig. 6. Petrographic thin sections with crossed nicols from Aguada del Fresco.

chalcedony perimetric end scraper, a hammerstone on basalt cobble, and a grinding artifact of alveolar basalt. The projectile point is complete, its size is medium-small, and was made bifacially, with extended and marginal retouch. End scrapers have small and medium-small sizes, respectively. They were made with marginal and partially extended retouch. In the case of the basalt artifacts, a very big complete cobble was selected to generate the hammerstone. On the other hand, the grinding artifact is fractured, very big, and has two polished sides, one of them concave. The tools made on silicified limestone consist of two bifaces, a notch, a

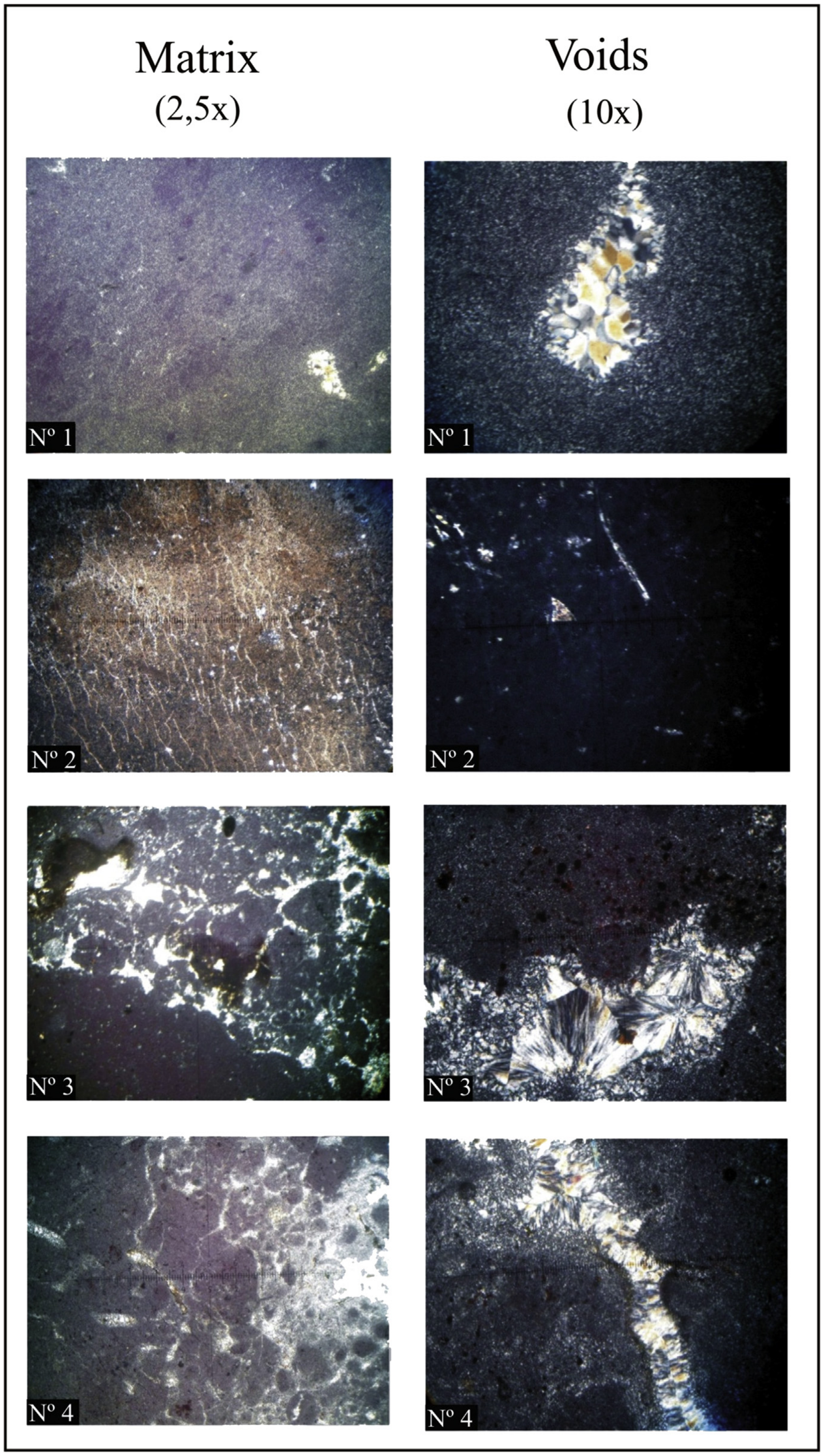

Fig. 7. Petrographic thin sections with crossed nicols from Estribación sur, cima.

composite artifact (flake with marginal retouch plus a notch) and a knife. The bifaces were made combining extended retouch with marginal retouch in one case. The other was produced by partially extended and marginal re-knapping. One is complete and big, while the other is fractured and its size is medium big. The other tools also have fractures and their sizes vary between the categories medium-big ($n = 2$) and big ($n = 1$). All of them were manufactured unifacially with marginal retouches.

The silicified limestone debris assemblage is formed by 211 elements, most of them fractured flakes ($n = 142$; 67.3%). They are

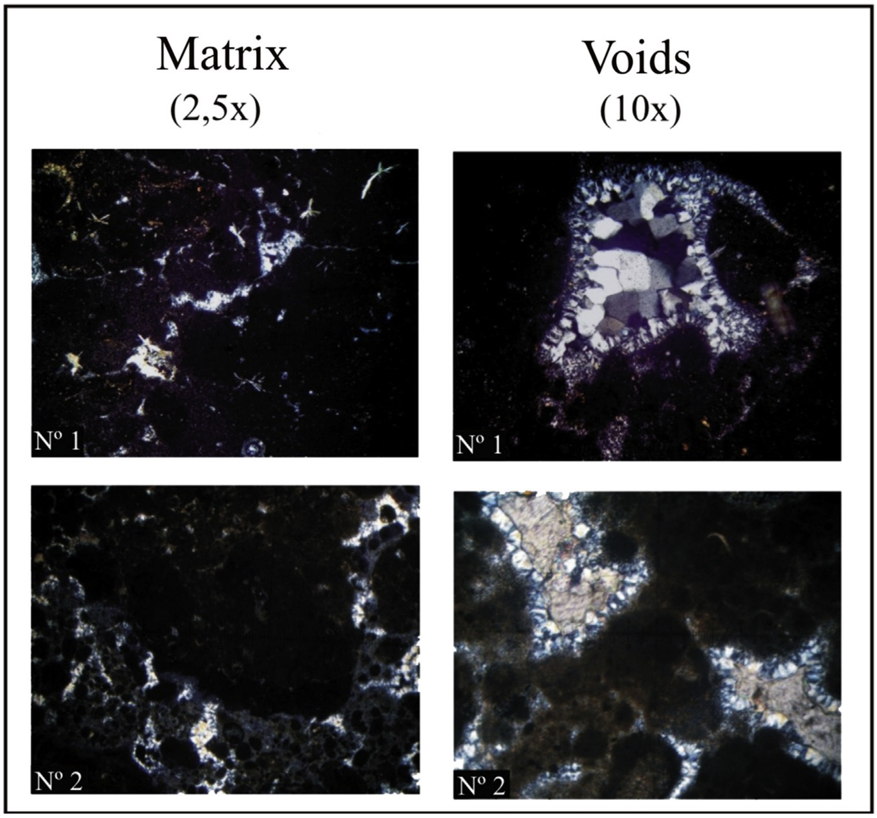

Fig. 8. Petrographic thin sections with crossed nicols from Cima del Cerro WP 81.

followed by unclassified debris ($n = 37$; 17.5%) and complete flakes ($n = 32$; 15.2%). Of the flake types, of the 97 items determined, most are internal ($n = 76$; 78.4%) and fewer are external ($n = 13$; 13.4%). Bifacial thinning flakes ($n = 5$; 5.2%), cleaning of platform flakes ($n = 2$; 2.1%) and tool re-sharpening ($n = 1$; 1%) were observed in low frequencies. In relation to the sizes, in the complete flakes all categories were registered, although medium-small ($n = 14$; 43.8%), small and medium-big ($n = 7$; 21.9%, each one) sizes are the ones that predominate. Three fractured flakes of chalcedony and two of silica were also detected. They are internal and small to medium-small sized. Due to its characteristics, it is considered that they could be linked to the maintenance of any of the tools made on these materials.

In the case of Aguada del Fresco, the artifacts recovered consist of 71 debris, 15 cores, and only one tool. Unlike Aguada de los Caballos, all elements were made in silicified limestone. With respect to the cores, the majority are complete ($n = 9$, 60%) and have very few cortex and impurities ($n = 3$ and $n = 4$, respectively), so, as with the previous case it is considered that there was a selection of raw materials of better quality for knapping. With respect to the sizes of the complete elements, the only registered categories are "very big" ($n = 5$) and "big" ($n = 4$). Based on the negative flake scars, it is considered that these cores produced flakes of medium-big to very big sizes.

The only tool recovered is a fractured medium-small sized flake that presents an edge made with marginal retouch. There is a predominance of fractured flakes ($n = 40$; 56.3%), and in lesser extent, complete flakes ($n = 19$; 26.8%) and undifferentiated debris ($n = 12$; 16.9%). With respect to the type ($n = 53$), the frequency of internal flakes ($n = 39$; 73.8%) is bigger than externals ($n = 12$; 22.6%). Two platform flakes were also identified. The sizes of complete flakes vary between medium-small and very big categories, although the first category is predominant ($n = 7$; 36.8%). The absence of small and very small debris is notable.

Archaeological evidence registered in Meseta del Fresco show that there was a differential use of the plateau. The highest density of archaeological record, coupled with a high frequency of lithic workshops, indicates that the rocks on the western slope were exploited more intensively than those located in the eastern sector. This could be associated with differences in the degree of silicification of rocks.

8. Discussion

8.1. Variability among rocks, flake quality and landscape use

The analyses developed account for the substantial variability in the degree of silicification of the rocks in Meseta del Fresco. According to the results observed in petrographic thin sections, silicifications are from partial to total throughout the landform, but in the top of Estribación Sur, Aguada del Chinchín, Cima del Cerro WP 81, Memoria del Fresco WP 75 and WP 76, the original texture of the rock is not recognized, indicating that the process of silicification was complete. By contrast, in Aguada del Fresco and Aguada de los Caballos, the original texture of the rock is observed, which is formed by peloids and skeletal fragments, though occasionally the presence of replaced fossils (for example, bivalves, gastropods, etc.) is also recorded. In this way and in general terms, Meseta del Fresco can be divided into two large sections: western, where the degree of silicification is high, and eastern, where the process is partial (except for Aguada del Chinchín where silicification is complete but has textural problems).

According to Aragón and Franco (1997), the texture is the main factor that determines the quality of the rock for flaking. In those cases where the matrix is finer, heterogeneities are better tolerated

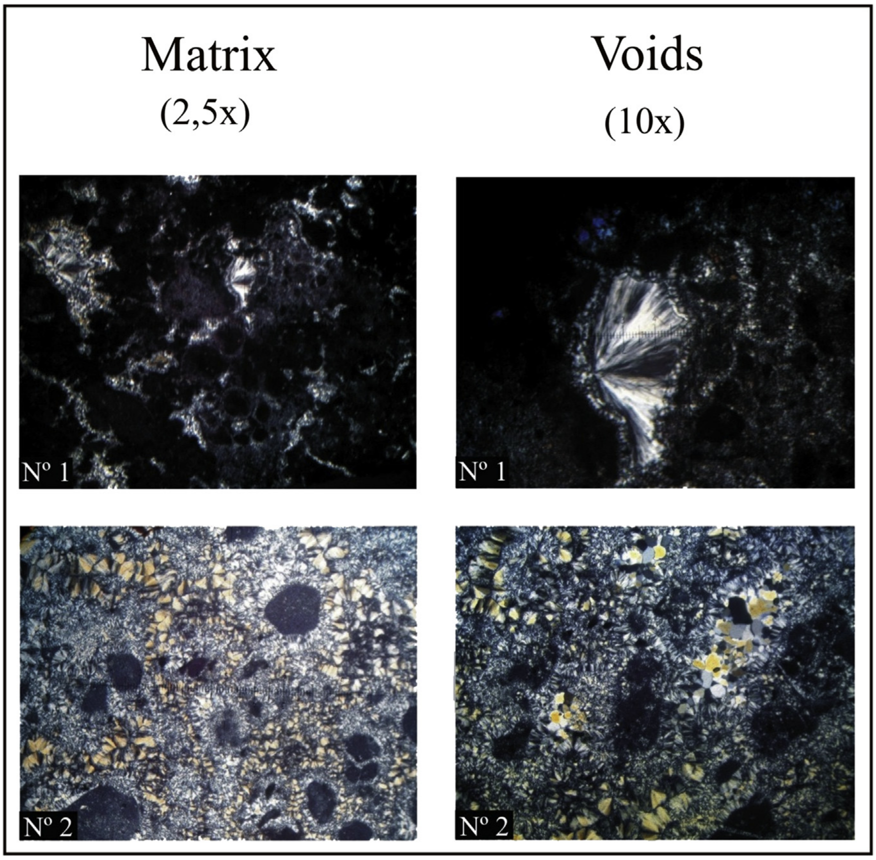

Fig. 9. Petrographic thin sections with crossed nicols from Memoria del Fresco WP 76.

and the quality of the rocks is less affected. Thus, better quality rocks are those in which the replacement is complete, the replacement of the matrix is cryptocrystalline, the original texture is hardly observed, and the presence of heterogeneities is low. In Meseta del Fresco, rocks with greater aptitude for flaking are those located on the western slope (Memoria del Fresco WP 75 and WP 76, Cima del Cerro WP 81) as well as at the southern end (top of Estribación Sur), while the rocks of eastern slope are of lesser quality (Aguada de los Caballos, Aguada del Freso). This is consistent with the archaeological record recovered in different areas of the plateau, suggesting that eastern slope was a place much less exploited, which could be linked to the lower degree of silicification of the rocks. An exception to this is Aguada del Chinchín, where silicification of the rocks is very high, but the archaeological evidence for the exploitation of raw materials is almost nil. Silicification in Aguada del Chinchín is mostly large pore fills of the original rock, and this can determine the presence of sectors with “weakness”, favoring random breakage in different directions. In this sense, these discontinuities in the silicification of the rock may act as fracture surfaces. This would be the reason for the absence of exploitation of this sector of the quarry, which otherwise has other suitable conditions for human settlement.

8.2. *Organic composition of the limestone*

Because limestones subsequently silicified are formed in aquatic environments, they often contain fossils of different organisms. They can be identified through the analysis of thin sections, and can generate information about the environment of formation of the raw material as well as its age (Uliana and Camacho, 1975). Otherwise, all rocks have a relationship, either in its mineral content and/or chemical composition, with its source. Due to this, the lithic artifacts are relevant evidence to discuss the home range and landscape use of the societies that employed them (Mangado, 2006).

The use of silicified limestones is registered from the first moments of human occupation during the Pleistocene–Holocene transition. These raw materials were used for making fishtail projectile points and other bifacial tools in at least three places in the province of Buenos Aires: the archaeological localities Cerro El Sombrero, Cerro La China (Flegenheimer et al., 2003) and the Paso Otero 5 site (Armentano et al., 2007; Martínez and Gutiérrez, 2011). From the archaeological record of the Pampas, three sources of these rocks were recognized to the present: Queguay and Arapey Formations, Uruguay (Flegenheimer et al., 2003; Bonomo and Blasi, 2011), and El Fresco Formation, La Pampa province (Berón and Curtoni, 2002; Berón, 2004, 2006; Curtoni et al., 2004). It was considered important to establish the place of origin of the rocks employed in the manufacture of such artifacts, in order to understand the home range of the early hunters. Flegenheimer et al. (2003) conducted a series of petrographic analysis on archaeological samples from Cerro La China and Cerro El Sombrero locations, as well as samples of the geological formations Queguay and Fresco. Based on the presence of gyrogonites of Charophytes in both, the archaeological samples and the Queguay Formation, and its absence in the sample of El Fresco Formation, it was postulated that the rocks used would have come from outcrops in Uruguay. In that work a single sample of Meseta del Fresco, a flake of silicified limestone of deep red color, commonly called “carneolita”, was analyzed. Therefore, it was possible that the variety of microorganisms in the Fresco Formation were underrepresented. However, the analyses performed in this study reject the hypothesis, as

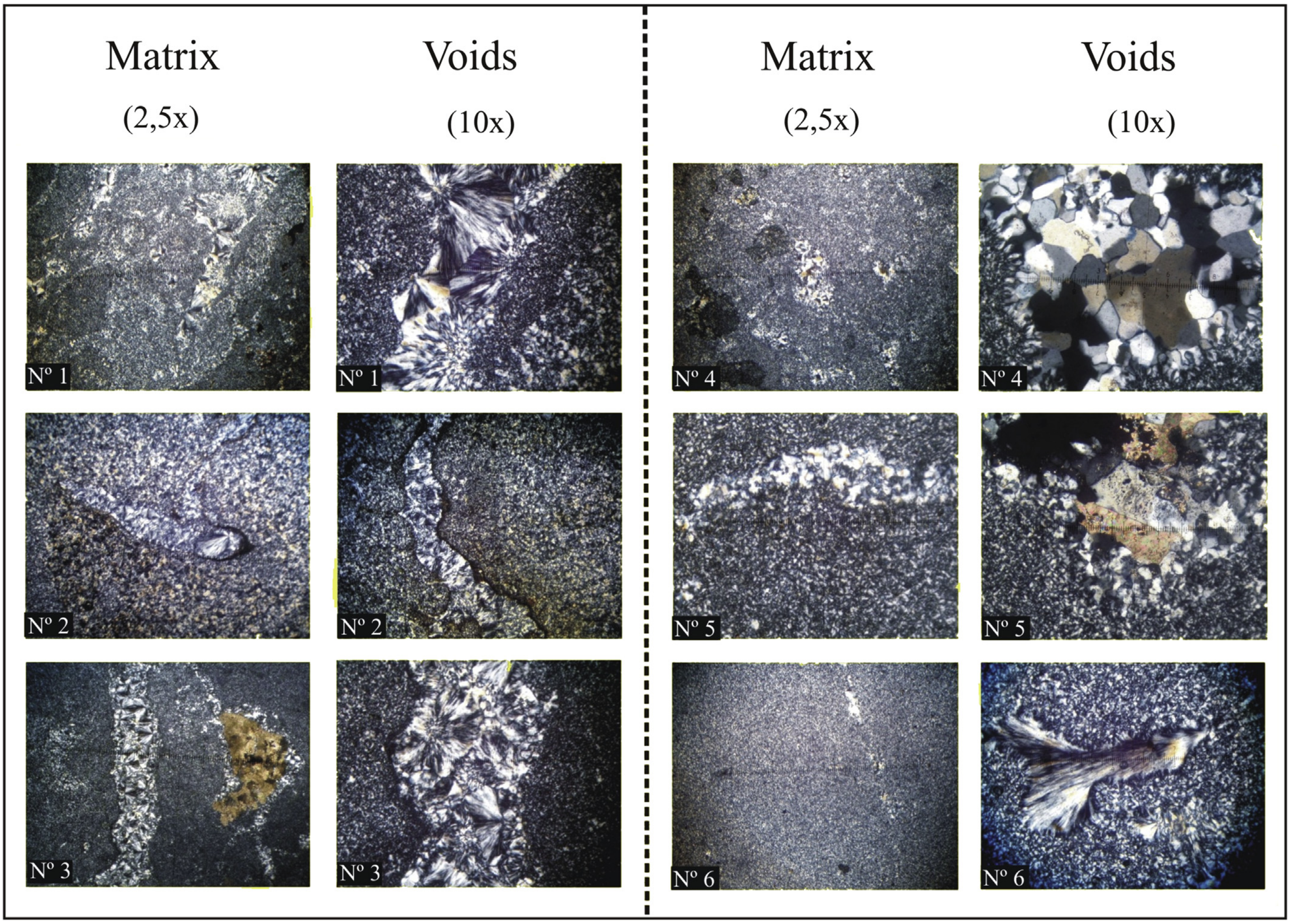

Fig. 10. Petrographic thin sections with crossed nicols from Memoria del Fresco WP 75.

the presence of oogonia was not recorded in any of the samples. Thus, the analysis of the thin sections indicates that the presence of charophytes seems to be a distinctive feature of the Queguay limestone.

8.3. *Meseta del Fresco use over time*

Through the dating of sites where the rocks from Meseta del Fresco are present, it is possible to determine indirectly the chronology of using this source of supply. The presence of siliceous chert from Meseta del Fresco has been recorded through almost the entire cultural sequence of site 1 in Tapera Moreira Locality. It is a base camp with multiple activities, with a chronological and cultural sequence spanning from the late Middle Holocene to the final late Holocene (Berón, 2004). However, silicified limestones are not present in the deeper levels of the site, but begin to be registered at level XXV, dated to ca. 3000 BP (Berón, 2004). In addition, silicified limestones are present in the Chenque I site, whose chronology ranges between 1050 and 290 BP (Berón and Luna, 2007; Berón et al., 2007), and in Laguna de Paisani site which was dated to 1210 ± 70 BP (Curtoni, 2007).

According to the statements, it is considered that the raw materials of Meseta del Fresco were exploited, at least, during the late Holocene. For Site 1 of Tapera Moreira Locality, they were absent during the stage of exploration of the landscape (sensu Borrero, 1994–95), but they have begun to be used during the initial stage of colonization of this and other environments of La Pampa province.

9. Conclusions

Meseta del Fresco is an extensive rock source of very good quality for flintknapping. According to petrographic thin sections analyzed, rock from facie V (sensu Melchor et al., 1992) is classified as silicified limestone, fully opalized and/or chertified, with bioclasts (shell, spicules and fragmented shells). The same, however, presents a significant internal variability, being the most silicified area in the northern foothills and the best quality for flaking in the southern foothill top and western slope. These differences are linked to the archaeological record, so that in the places where rocks present better flintknapping qualities, the sites with greater abundance and variability of lithic artifacts are located.

The importance of Meseta del Fresco as source of supply for hunter–gatherers, is shown by the numerous and extensive workshops identified in the vicinity (Berón and Curtoni, 2002; Curtoni et al., 2004). The evidence provided by different sites in the Pampas region contains lithic assemblages with artifacts that, macroscopically, were manufactured with the rock of Meseta del Fresco. In Western Pampa, its use has been verified in different subareas: in Northcentral, Don Isidoro site (Charlin, 2002), in Midwest, in Manantial Naicó, Parque Luro and Laguna de Paisani (Carrera Aizpitarte et al., 2007; Curtoni, 2007; Carrera Aizpitarte,

Fig. 11. Lithic artifacts concentration in Taller 1 site. At the bottom, Meseta del Fresco.

Fig. 12. Blocks with large evidences of edgebanding. Estribación sur.

2010), in South Central, Laguna El Carancho (Berón, 2004, 2006) in several sites of archaeological localities Lihué Calel and Tapera Moreira (Berón, 2004, 2006); in Transversal Valleys, sites San Sixto, La Cascada, Bajo de Marcelino, Médanos de Costilla and La Tigra (Berón et al., 2007); in Bajos sin Salida, sites La Chola, La Colorada Grande and Médano La Enriqueta (Berón et al., 2007; Carrera Aizpitarte et al., 2013; see Fig. 2).

In the Humid Pampas subregion, the frequency is lower, although their identification has not been as comprehensive as in West Pampa, so this rock could be part of the silicas as a generic category, or an indeterminate rock. They were recognized in the sites El Puma 3 (Santos Valero, 2013), Caldén Guazú (Armentano, 2012), Laguna La Barrancosa 2 and Arroyo Tapalqué 1 (Messineo, 2008), Arroyo de los Pampas (Politis et al., 2012) and Las Brusquillas 1 and 3 (Massigoge, 2011, 2012) (see Fig. 2).

Finally, we believe that the data presented here represent a significant advance on the lithological characteristization of Meseta del Fresco. Otherwise, petrographic thin sections may be used as a database for colleagues working in neighboring areas, in order to compare rocks recovered at different sites and query their possible origin of this source of supply.

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