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# Grinding, Processing, and Reuse: An Integrated Functional and Microbotanical Study of Polished Stone Artifacts from the Southern Pampean Hills (Ongamira and Characato, Córdoba, Argentina)

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## Abstract

The study of hunter-gatherer societies and their transition toward food-producing lifeways is a central topic of ongoing debate in central Argentina. This paper presents an integrative analysis of lithic artifacts manufactured through pecking, abrasion, and polishing techniques from two archaeological localities in the Southern Pampean Hills of Córdoba, Argentina: The Ongamira valley (Ischilín Department) and Characato (Cruz del Eje Department). Combining techno-morphological, microbotanical and traceological analyses, we reconstruct artifact life histories, estimate possible functions, and explore daily practices related to plant processing. Microscopic analysis revealed numerous use-wear traces associated with plant resource processing, along with starch grains and phytoliths from both wild and cultivated taxa. The evidence includes wild species characteristic of the Chaco Serrano Forest, the biogeographical region where the sites are located, as well as cultivated plants associated with small-scale horticultural practices typical of the last two thousand years of human occupation. This integrated approach provides valuable insights into production strategies, plant exploitation practices, and the processes of change underlying the transition from hunter-gatherer to food-producing lifeways in central Argentina.

## INTRODUCTION

Globally, grinding artifacts constitute a key archaeological component for understanding subsistence strategies and economic changes in human societies. Artifacts such as mortars, handstones, grinding slabs, or conanas are associated with the intensive exploitation of plants and other resources, both in hunter-gatherer contexts and in food-producing societies, including small-scale horticultural practices and more extensive agricultural systems (e.g., Wright 2017; Jerusalem Post Staff 2024). Ethnoarchaeological and experimental studies show that ground stone tools not only played a role in food preparation and transformation but also provide insights into the social organization of labor, task specialization, and the processes of productive intensification and increasing sedentism.

Compared to regions such as the Near East, Mesoamerica (Piperno 2012; Pickersgill 2007), and the central Andes (Pearsall 2008; Piperno 2012), where plant domestication and the establishment of agricultural economies date back to the Early and Middle Holocene (*ca.* 10,000–5,000 BP), in what is now Argentina these processes followed a different trajectory. Although early evidence of domesticated plants exists in Northwestern Argentina—for instance, at Huachichocana III (Jujuy), with records of maize, bean, and *Capsicum* dating to *ca.* 9,600–8,700 BP (Pearsall 2008)—these findings correspond to discrete events and do not imply the immediate consolidation of fully structured agricultural systems.

Various studies indicate that the systematic organization of production, the intensification in the use of cultigens, and their articulation with transformations in settlement patterns and social organization are most clearly documented during the Late Holocene, particularly between *ca.* 2,500 and 1,000 BP, with notable development in later periods such as the Regional Developments period (ca. 1,200–550 BP) (Capparelli et al. 2015). In this sense, although agriculture in Argentina has earlier antecedents in the Northwest, its consolidation as a central economic system and as a driver of social reorganization occurred later compared to the primary centers of early domestication in the Americas. In this context, several studies have characterized grinding lithic assemblages to discuss their production, use, and discard, noting the selection of local raw materials and possible processes of resource intensification (Vecchi and Gonzalez 2018; Saghessi and Matarrase 2021; Cunietti 2024). Likewise, archaeobotanical and microremain analyses applied to grinding artifacts have begun to document the presence of plant remains (such as starch grains) that directly contribute to the reconstruction of diets and plant processing practices in pre-Hispanic societies of what is now Argentina (Babot et al. 2007; Ciampagna et al. 2020).

In central Argentina, studies on ground stone assemblages have experienced progressive development in recent decades. A key antecedent is the work of Roldán (1999), who proposed a comprehensive approach from a morphological-functional, petrological, experimental, and use-wear perspective. This approach broadened the understanding of the technological and functional diversity of these artifacts in highland contexts. However, for a long time, cultural elements produced through pecking, abrasion, and polishing techniques were relegated to general descriptions or basic typological classifications, despite their central role in activities related to plant resource processing. From the pioneering contributions of Lehmann-Nitsche (1903), as well as the First National Convention of Anthropology (1996), to the comprehensive approaches developed by Babot (2004), significant progress has been made toward a broader understanding of these artifacts as part of complex technological systems. Following Babot (2004):

Grinding artifacts can be defined as those utensils used in pairs to break or reduce non-artifactual intermediate substances to a size smaller than the original. Thus, their essential characteristics are: (a) they require at least two parts to function, which complement each other; (b) the purpose of their use is not to reduce their own size, but rather that of other substances that are not artifacts; and (c) these substances must be placed between the two artifact parts in order to be processed. (p. 83)

The discovery of these artifacts is frequent in the study region, which has allowed advances in understanding the occupation dynamics of residential sites, both in open-air settings and in rock shelters (e.g., Pastor 2007; Rocchietti and Ribero 2017; Cattáneo and Izeta 2016; Robledo 2020; Sario et al. 2023; Brizuela 2025; Rivero et al. 2025, among others). Nevertheless, their detailed study remains relatively scarce and, in many cases, has focused on specific contexts, particularly those associated with the recovery and analysis of plant microremains (Medina et al. 2009; López 2017; Rivero and López 2010; Recalde and López 2017, among others).

Likewise, this type of archaeological record has been recovered and analyzed more frequently in contexts corresponding to the Late Holocene (ca. 4200–300 BP). The earliest evidence of plant processing using *conana* handstones in Córdoba comes from the site El Alto 3, in the Pampa de Achala, where microremains associated with grinding tools were identified, dated to 7108 ± 74 14C BP, constituting the oldest records of this kind in the region to date (Rivero and López 2010). However, it is during the final moments of the Late Holocene that more flexible subsistence and mobility patterns are proposed, linked both to small-scale food production (e.g., horticulture) and to the gathering of plant fruits, depending on seasonal availability and the social conditions of the environment (Pastor et al. 2012; Medina et al. 2014; López 2017).

Taken together, global and regional evidence underscores that the comprehensive study of grinding artifacts through techno-morphological, functional, and residue analyses is crucial for discussing not only plant exploitation and the transition to agriculture, but also the social and economic dynamics of prehistoric populations at different spatial and temporal scales. In this regard, the present work aims to integratively analyze grinding artifacts from the Ongamira valley and the locality of Characato, based on the morphological-functional study of active surfaces and the identification of preserved microremains. Through this approach, we seek to deepen the understanding of the uses of these artifacts and the daily practices associated with plant resource processing, attending to the persistence in raw material selection, manufacturing techniques, and the exploitation of certain wild and cultivated plants throughout the Holocene.

## Study Area and Archaeological Background

The study area comprises two sectors of the mountainous region of the Punilla valley in the Sierras de Córdoba: The Ongamira valley, located north of the valley and northwest of the city of Córdoba, and the locality of Characato, situated in the western sector of the Punilla valley, approximately 132 km from the provincial capital, including Villa Characato and the locality of El Palmar (Fig. 1).

For the Ongamira valley, artifacts from six previously recorded archaeological sites in the region were analyzed. These include both rock shelters: Alero Deodoro Roca (ADR), Parque Natural Ongamira 1 (PNO 1), and Parque Natural Ongamira 5 (PNO 5); as well as open-air sites: La Cuesta de la Mula Negra 1 (LCMN 1), Molle de Piedra 1 (MDP 1), and Molle de Piedra 3 (MDP 3). In turn, the sites from which the samples from the Characato locality originated correspond to one cave or rock shelter, Cueva 1 (C 1), and two open-air sites: El Dique (ED) and Taller 1 (T 1).

In the Ongamira region, archaeological research has enabled the systematic recovery of grinding stones and other ground stone artifacts from occupation contexts, both at open-air sites and in rock shelters. In recent years, specific sectors associated with grinding activities have been identified through the presence of mortars (Conte and Robledo 2020; Robledo 2020). Within this framework, nine granite blocks with one or more cavities have been recorded, located both in areas near watercourses and in flat zones of the valley (900 m.a.s.l.) as well as in highland sectors (1100 m.a.s.l.). Additionally, seven smaller blocks, potentially transportable, were identified. This assemblage suggests grinding practices that would have taken place either individually or communally, depending on the type of support and specific needs (Robledo 2020).

For the Characato region, surveys conducted recorded a high variability of passive grinding artifacts (mortars and grinding slabs), both fixed and mobile, distributed across current domestic areas, private properties, and landscape sectors associated with rock outcrops. Fixed mortars carved into bedrock were identified, with contiguous and isolated cavities, as well as mobile grinding slabs and mortars manufactured on granite, with diverse morphologies (spherical and oval) and grinding surfaces defined by concavity or horizontal displacement. Additionally, a large granite structure located near the main road of the town stands out, which concentrates ten mortars (some of them incipient) and presents evidence of block rearrangement, possibly related to the opening of the road. In the El Palmar sector, the site "Los Morteritos" corresponds to a rock shelter with mortars and small cupules (3–18 cm in diameter and depths ≤ 3 cm), including an external mobile rock with approximately forty cupules. To these records are added assemblages of mortars on metamorphic rocks at Mesa del Palmar, as well as isolated finds at Estancia and Chacra Grande, where evidence of abrasion and polishing consistent with repeated use was documented (Brizuela 2025).

In general, the morphological, dimensional, and contextual diversity of these artifacts suggests prolonged and repeated use trajectories, as well as possible processes of reuse and functional reconfiguration over time—aspects that are central to addressing their analysis from a functional perspective.

In relation to these use trajectories, various studies have indicated that systematic maintenance or reactivation of the pieces is not essential, and that even fractured artifacts can continue to be used without being discarded, despite their low replacement costs (Babot and Larrahona 2010). It has been documented, for example, that some grinding stones were used even with uncomfortable breaks in the gripping areas, while others, once irreparably fractured, were replaced by previously used implements, resulting in artifacts with multiple active surfaces. This pattern of extended use reflects the high labor investment involved in their manufacture and the functional—and potentially symbolic—value they acquired within the use sequence of these instruments.

Within this framework, understanding the production and use strategies of lithic artifacts requires attending not only to their morphology and archaeological context, but also to the physical processes involved in their operation. From this perspective, functional analysis—also known as traceology or tribology—focuses on the study of the interaction between surfaces in relative motion, with emphasis on friction, wear, and lubrication (Quinn 1971; Czichos 1978; Szeri 1980). It has been documented that during friction, fundamental transformations occur in the surface volumes of the materials in contact, determining both the wear process and the magnitude of the friction force (Kragelsky et al. 1982), with this damage being cumulative and sensitive to small variations in material properties.

Closely related to these processes, the analysis of kinematics—understood as the study of the type of motion applied during the use of an instrument—becomes relevant. Since the pioneering work of Semenov (1964) and Keeley (1980), as well as numerous contributions developed in Argentine archaeology (Mansur 1983, 1986; Álvarez et al. 2000; Cattáneo and Fernández-Ordoñez 2005; Cattáneo 2006; Leipus and Mansur 2007; Cueto and Frank 2010; Pal 2015; De Angelis 2016; among others), it has been emphasized that the type of motion employed during the use of instruments provides key information about the processes of material transformation, the technical organization of labor, and the efficiency of the tasks performed.

In this sense, the detailed identification of wear processes and transformation of active surfaces not only contributes to understanding the technical functioning of instruments and the exploitation of plant resources, but also offers a means to reconstruct aspects of the social dynamics and daily practices that marked the life of highland groups in the past.

# Environmental and Phytogeographic Characterization of the Study Region

As mentioned above, this study is carried out in two sectors of the mountain region of Córdoba: Ongamira, in the Sierras Chicas, and Characato, in the Sierras Grandes. Both share a general environmental framework, although they exhibit local variations primarily associated with altitude and topographic configuration. From a climatic perspective, the Sierras de Córdoba constitute a mountain system with temperate conditions, marked seasonality, and high environmental heterogeneity, influenced by the proximity of arid regions but defined by local dynamics specific to the mountainous terrain (Abraham de Vázquez et al. 2000; Izeta et al. 2017). Mean annual temperatures range between 12°C and 18°C in low-lying areas, dropping to values near 7.5°C in the higher altitude sectors. Likewise, significant daily temperature ranges are recorded in both sectors, particularly during the winter period (Silva et al. 2011; Yanes et al. 2014).

Regarding vegetation, the Chacoan Domain occupies a large portion of central Argentina and neighboring countries. From a floristic perspective, it is characterized by the abundance of families such as Leguminosae, Zygophyllaceae, Anacardiaceae, Celastraceae, and Rhamnaceae (Hernández and Giménez 2016). The Chaco Serrano Forest is a deciduous xerophytic forest, composed mainly of species such as quebracho colorado (*Schinopsis lorentzii*), molle de beber (*Lithraea molleoides*), and coco (*Zanthoxylum coco*). In lower or more open areas, there may be presence of tala (*Celtis tala*), quebracho blanco (*Aspidosperma quebracho-blanco*), espinillo (*Vachellia caven*), sombra de toro (*Jodina rhombifolia*), and aguaribay (*Schinus areira*), among others (Cagnolo et al. 2006).

In Ongamira specifically, highland grasslands dominated by grasses of the genera *Stipa* and *Festuca* prevail above 1000 m.a.s.l. Meanwhile, in the valley bottom and ravine (900 m.a.s.l.), where humidity is higher, woody species such as algarrobo negro (*Neltuma nigra*), molle (*Lithraea molleoides*), and tala (*Celtis tala*) are preserved. These environments also harbor species of traditional use, such as mistol (*Sarcomphalus mistol*), piquillín (*Condalia microphylla*), atamisqui (*Atamisquea emarginata*), and jarilla (*Larrea divaricata*), along with medicinal and aromatic plants and ferns that thrive in humid or shaded microhabitats, particularly in rock shelters, within the Saldán Formation characteristic of Ongamira (Zárate in Cattáneo and Izeta 2016).

In the Characato area (at approximately 1000 m.a.s.l.), the plant landscape also corresponds to the Chaco Serrano, with a transitional formation between the dry Chaco forests and highland grasslands. This environment features an open arboreal structure and marked rainfall seasonality (Cabido et al. 2018; Giorgis et al. 2021). On the slopes and in ravines, mixed communities of typical native woody species predominate, such as algarrobo negro (*Neltuma nigra*), moradillo (*Schinus fasciculatus*), chañar (*Geoffroea decorticans*), tala (*Celtis ehrenbergiana*), and piquillín (*Condalia microphylla*). Particularly in this sector, the presence of quebracho (*Schinopsis marginata*) and garabato macho (*Senegalia gillesii*) forests stands out, although in some areas, mainly following forest fires, "romerillar" and "highland grasslands" dominate, characterized by *Pteridium arachnoideum* and Caranday palm (*Trithrinax campestris*) (Weihmüller et al. 2022; Naval Fernández et al. 2023).

## Archaeobotanical Evidence and Plant Management in the Sierras de Córdoba

Archaeobotanical studies developed in the mountainous region of Córdoba have advanced significantly in recent years, integrating different lines of evidence that contribute to the reconstruction of lifeways and subsistence strategies of pre-Hispanic populations since the Middle Holocene. Although initial research relied mainly on colonial documents that mentioned the gathering of wild fruits—such as algarrobo (*Neltuma* sp.) and chañar (*Geoffroea decorticans*)—and the consumption of cultivated plants—such as maize (*Zea mays*), squash (*Cucurbita* sp.), and beans (*Phaseolus* sp.)—direct analyses of plant macro- and microremains have provided concrete evidence that confirms and expands these observations.

Recent research (Tavarone et al. 2020, 2021; Medina et al. 2009) has identified remains of maize, squash or pumpkin, and beans in their pallar and common varieties (*Phaseolus lunatus* an *P. vulgaris*, respectively), through the analysis of both macroscopic and microscopic botanical remains. This evidence comes from different archaeological contexts, including human dental calculus with chronologies ranging between 1280 ± 15 and 383 ± 58 BP (Tavarone et al. 2020, 2021), as well as from sedimentary matrices, ceramic fragments, and grinding artifacts (Ábalos and Tavarone 2024; Pastor and López 2010; Medina et al. 2009). Together, these data indicate the development of diverse horticultural and plant management strategies in the mountainous region.

Regarding wild species, archaeobotanical evidence confirms the recurrent use of algarrobo (*Neltuma* sp.), mistol (*Sarcomphalus mistol*), chañar (*Geoffroea decorticans*), caranday palm (*Trithrinax campestris*), tala (*Celtis ehrenbergiana*), piquillín (*Condalia microphylla*), molle de beber (*Lithraea molleoides*), and wild bean (*Phaseolus vulgaris* var. *aborigineus*) (Medina et al. 2009; Tavarone et al. 2021; Palmieri et al. 2026, among others). In the same vein, lithic and microbotanical analyses conducted by Heider and López (2016) on grinding artifacts from hunter-gatherer sites in northern Pampa Seca (San Luis and Córdoba) evidenced the processing of a wide diversity of wild plant resources, among which algarrobo (*Neltuma* sp.), chañar (*Geoffroea decorticans*), and species of *Vachellia* stand out. They also identified siliceous microremains of maize and starch grains compatible with tubers, although without precise taxonomic assignment.

For the Ongamira valley, Romanutti et al. (2025) recorded the presence of seven wild taxa characteristic of the Chaco Serrano Forest in contexts dated between *ca.* 4500 and 3500 BP, including representatives of Amaranthaceae, Asteraceae, Fabaceae, and Poaceae. Taxa with potentially edible fruits (such as *Celtis* sp., *Cereus* sp., and *Neltuma* sp.) were also identified, with a higher concentration toward *ca.* 3600 BP, reinforcing the relevance of these resources in local food practices.

The use of wild woody species as fuel has been addressed to a lesser extent in the region (López 2006; Franco-Salvi 2007; Robledo 2021; Chávez 2024). In Ongamira, a more systematic study of combustion events has documented a high taxonomic diversity—over 20 species—generally interpreted as

firewood available in the immediate environment throughout the Middle and Late Holocene, although with the possible incorporation of some taxa from nearby areas (Robledo 2020, 2021).

Taken together, these antecedents support interpretations proposing a flexible and complementary economy (Laguens 1999), characterized by the sustained articulation between wild and cultivated plants. Thus, even though the incorporation of horticultural practices in the region was relatively late, the intensive use of wild species remained a structural component of subsistence strategies throughout the Late Holocene.

In this context, grinding artifacts have been recognized at numerous highland sites and are frequently linked to plant processing and changes in subsistence strategies. However, their study has largely privileged chronological association and potential functional interpretations in a general sense, while aspects related to their technological variability, maintenance, reuse, and use dynamics have received less systematic attention. This situation has limited the possibility of comprehensively understanding continuities and transformations in grinding technical traditions in the region.

# METHODOLOGY

This study focuses on the analysis of 16 granite artifacts from two mountainous areas of the province of Córdoba: Ongamira (n = 11) and Characato (n = 5). The assemblage was addressed through an integrative methodology that combines archaeobotanical analyses with morpho-typological and functional studies based on microscopic examination.

## Plant Microremain Analysis

First, archaeobotanical analysis of organic residues adhered to the artifacts was carried out, with the aim of identifying plant microremains associated with their use. Among the potentially recoverable elements, starch grains and siliceous phytoliths were primarily considered, as they provide relevant information about the plant species manipulated and the daily practices linked to plant use in the past.

The study of microremains followed the protocol proposed by Musaubach (2017) for their recovery and analysis. The active and passive surfaces of the artifacts were carefully scraped, selecting specific sectors such as edges, cavities, and areas with possible visible residues—such as remains of pigments or stains of indeterminate substances—as well as areas without apparent evidence, in order to cover different contexts of preservation and use.

The recovered material was mounted in cedarwood oil and analyzed using optical microscopy (Leica Microsystems DM4500, 40×). The study included systematic recording, photographic documentation, and quantification of the observed microremains. Phytoliths were described based on an *ad hoc* classification developed according to the criteria of ICPN 2.0 (Neumann et al. 2019) and compared with specialized reference collections. In the case of starch grains, their identification was carried out following the guidelines of the ICSN (2011) and the qualitative-quantitative criteria developed by Giovannetti et al. (2008) and Korstanje and Babot (2007), among other reference sources.

## Morpho-typological and Macro-functional Analysis

Second, a morphotypological and macrofunctional analysis was developed aimed at characterizing artifacts manufactured by pecking, abrasion, and polishing, as well as those modified primarily by use. This analysis included the identification of potential raw material sources at the regional level, considering the availability, diversity, and abundance of rock types documented both from field surveys and cartographic and geological sources.

The classification of the assemblage was carried out based on morphological, technological, and functional attributes, following the methodological guidelines proposed by Aschero (1975, 1983), Escola (1993), Adams (1988), Babot (2004), and Matarrese (2015). Different types of artifacts linked to grinding, percussion, and raw material manipulation activities were identified, including conanas (C), conana handstones (CH), mortars (M), mortar handstones (MH), hammerstones (H), anvils (A), lithics modified by use (LMU), and lithics with adhered residues (LAR). Likewise, rock fragments with evidence of thermal fracture (RTF) and samples selected for specific analyses (SA) were recorded.

Each piece was examined considering the raw material used in its manufacture, mainly granites and metamorphic rocks of local origin. Granulometry was evaluated (fine homogeneous: 1; coarse heterogeneous: 2) and metric dimensions (length, width, and thickness) were recorded in millimeters.

The base form of the artifacts was classified according to their origin and general morphology, differentiating primary and secondary forms (*sensu* Aschero 1975). The former correspond to rocks found in their place of origin, either consolidated or as natural detachments, while the latter refer to materials transported from their primary sources, generally in the form of river cobbles or nodules (Nami 1992). Within these categories, various morphological variants were recognized: pebbles of circular, oval, or very thick elliptical section (PCOE); pebbles of elongated or flattened elliptical section (PEFE); pebbles of flat-convex section (PFC); natural half-pebbles (NH); faceted nodules or cobbles (FNC); tabular nodules (TN); non-rolled slabs (NRS); blocks (B); and undifferentiated nodules (UN). Likewise, the state of fragmentation was recorded, distinguishing between whole pieces (W) and broken pieces (B), and the functional condition of the instruments was classified as active elements (A) or passive surfaces (P).

Regarding primary functions, the different "actions or modes of operating the instruments" (Aschero 1975:4) were considered, understood as the most suitable effects that each artifact can produce on the worked material. In this sense, mortar handstones were associated with tasks of mashing, grinding, pulverizing, and crushing (MGPC), while *conana* handstones were linked to grinding, pulverizing, and crushing (GPC). Mortars, *conanas*, and anvils were defined as supports (S), given their passive function within the grinding system, and hammerstones were assigned to the percussing category (P), associated with direct or indirect percussion actions.

Finally, modes of action were differentiated according to the mechanics of the applied movement: percussion, whether vertical or pointed (PVP), and pressure, exerted in a sliding manner or with displacement (PSD), considering the type of contact and the direction of force on the active surface.

## Microscopic Functional Analysis (Traceology)

Finally, a microscopic functional analysis was carried out aimed at identifying use-wear and taphonomic alterations. This study allows us to approach the grinding practices developed in the Sierras de Córdoba through the analysis of artifacts directly linked to these activities, such as grinding slabs, mortars, grinding stones, hammerstones, and/or anvils. Although these instruments are common in regional archaeological contexts, their functional assignment based on direct evidence of use observed on surfaces has been addressed in a limited manner to date.

The traceological analysis followed the methodological guidelines proposed by Semenov (1964), Keeley (1980), and Mansur (1986, 1999), among others. An optical approach was adopted at two observation levels, organized progressively for the diagnostic study of use-wear. In the first stage, observations were made using a Motic stereomicroscope (less than 100X, generally at 40X), in order to identify macro-wear visible at low magnification, such as fractures, chipping, abrasion, and rounding (Kamminga 1979). When identified, these traces were recorded according to a gradual intensity scale (low, medium, high).

Subsequently, analysis was carried out using an inverted Motic metallographic microscope (between 100X and 500X, usually between 100X and 200X), aimed at recording micro-wear such as polishes, micro-residues, scarred surfaces, crushed or pecked areas from use, striations and their directionality, as well as other technological features (Mansur 1983). Images were captured at 200× for this publication.

Prior to microscopic analysis, the artifacts underwent a controlled cleaning process. In this case, for the granite pieces, soapy water and a soft to medium bristle brush were used to remove adhered sediments that hinder the observation of use-wear. Once cleaned, the pieces were handled exclusively with gloves to prevent subsequent contamination.

For the Ongamira valley, 11 grinding artifacts from six previously recorded archaeological sites in the region were analyzed, coming from rock shelters: ADR, PNO 1, and PNO 5; as well as from open-air sites: LCMN 1, MDP 1, and MDP 3. For the Characato locality, five grinding artifacts from three archaeological sites were analyzed, corresponding to one cave or rock shelter: C 1; and two open-air sites: ED and T 1.

Table 1
Archaeological provenance of the analyzed samples

| Sites | Type of context | Provenance | Samples Number (Code) | Chronology | References |
|---|---|---|---|---|---|
| Ongamira valley | | | | | |
| **ADR** | Rockshelter - Occupation frame between ca. 900 to 6500 YBP - SU143 refill from excavations in late 50s - SU157 stratigraphic layer with evidence of pottery and lithic (quartz) technology. | Superficial | **3** (2309)<br>**6** (2317) | Late Holocene | Brizuela 2025; Cattáneo e Izeta 2016 |
| | | SU143 | **1** (5765) | Menghin y González (1954) excavation fill | |
| | | SU157 | **2** (21408/2)<br>**4** (21408/1) | Under a layer dated to 1823 ± 20 years BP | |
| **PNO1** | Rockshelter - Occupation frame between *ca.* 1900 to 5700 YBP - SU6 stratigraphic layer associated a pottery technology - SU49 combustion event with fauna remains and lithic technology | SU6 | **11** (5440) | Under a layer dated to 1905 +/- 20 years BP (YU-7746) | Robledo 2020 |
| | | SU49 | **9** (2600) | | |
| **PNO5** | Rockshelter - Occupation frame between *ca.* 950 to 2900 YBP - SU3 stratigraphic layer associated to combustion evidence, faunal remains and lithic ensemble | SU3 | **5** (4383) | Dated 942 ± 20 years BP (YU-7749) | Robledo 2020; Brizuela 2025 |
| **LCMN1** | Rockshelter - related to Late Holocene contexts with presence of pottery technology | SU1 | **7** (4499) | Late Holocene | Conte y Robledo 2019; Robledo 2020 |
| **MDP1** | Open air - related to Late Holocene contexts with presence of pottery technology - Excavation made near a mortar | SU1 | **8** (4487) | Late Holocene | |
| **MDP3** | Open air - related to Late Holocene contexts with presence of pottery technology - Excavation made near a mortar | SU1 | **10** (2988) | Late Holocene | |
| **Characato valley** | | | | | |
| **Cueva 1** | Rockshelter - related to Late Holocene contexts with presence of pottery technology - Associated to lithic ensemble (quartz) | Superficial | **14** (20006/1)<br>**15** (20006/2)<br>**16** (20086) | Late Holocene | Brizuela 2025 |
| **El Dique** | Open air - related to Late Holocene contexts with presence of pottery and lithic technology | Superficial | **12** (22467) | Late Holocene | Brizuela 2025 |
| **Taller 1** | Open air - related to Late Holocene contexts with presence of lithic technology ensemble | Superficial | **13** (37) | Late Holocene | Brizuela 2025 |

## RESULTS

# Plant Microremain Analysis

In the Ongamira valley, microbotanical analyses conducted on the various artifacts reveal the recurrence of phytoliths and starch grains associated with both wild and cultivated plants, pointing to a diverse selection of plants exploited throughout the Holocene (Table 2; Figs. 3 and 4):

Sample No. 1 constitutes one of the most extensive records, with phytoliths of Poaceae (rondel, saddle, and elongate) and starches corresponding to wild tubers, potato (*Solanum tuberosum*), squash or pumpkin (Cucurbitaceae), bean (*Phaseolus* sp.), maize (*Zea mays*), and algarrobo (*Neltuma* sp.), an assemblage that suggests prolonged and intensive use of the artifact in the processing of resources of different origins.

Specimens No. 2 and 4 provide a coincident repertoire: both contain siliceous phytoliths and starches associated with algarrobo (*Neltuma* sp.), along with pollen grains of the Amaranthaceae–Chenopodiaceae complex. This recurrence reinforces the idea that the two instruments were part of the same functional set oriented toward plant processing.

Artifact No. 3 adds fragments of plant tissues, fibers, and bulliform, elongate, saddle, and spheroid phytoliths, as well as circular starch grains and lepidopteran scales. Meanwhile, sample No. 6 presents Poaceae phytoliths (elongate, bilobate, rondel, saddle, and spheroid), starches of maize (*Zea mays*), algarrobo (*Neltuma* sp.), and crushed wild tubers, in addition to two globular trichomes, an assemblage pointing to diversified processing practices.

Sample No. 5 presents gelatinized starches potentially linked to maize (*Zea mays*), accompanied by elongate, bilobate, and saddle phytoliths, while in sample No. 7, phytoliths corresponding to the Poaceae family were recorded—of the elongate, bilobate, rondel, blocky, and saddle types—along with epidermal tissues, conglomerates of gelatinized starches of algarrobo (*Neltuma* sp.), a diatom possibly related to *Hantzschia amphioxys* (associated with freshwater environments), and a fragmented pollen grain.

For specimen No. 8, crushed starches associated with algarrobo (*Neltuma* sp.) and others linked to piquillín (*Condalia microphylla*) predominate, along with elongate, bilobate, and blocky phytoliths, while sample No. 10 again records starches related to algarrobo (*Neltuma* sp.) and Poaceae phytoliths in their bilobate, elongate, and bulliform forms, reinforcing the systematic presence of wild species within the assemblage.

In sample No. 9, gelatinized starches associated with algarrobo (*Neltuma* sp.), plant fibers, Poaceae phytoliths—mainly elongate, blocky, and flabelate—and fragments of epidermal tissue were recorded, while in sample No. 11, conglomerates of starches related to algarrobo (*Neltuma* sp.) were identified, along with epidermal and conductive tissues, plant fibers, and Poaceae phytoliths (elongate, blocky, and bulliform). Likewise, two pollen grains were identified—one possibly linked to *Neltuma* sp. and another without taxonomic determination—in addition to starch grains with evidence of grinding damage and a grain related to an unidentified wild tuber.

In Characato, microbotanical analyses conducted on the various samples reveal the combination of wild and cultivated plants, reflecting diverse and flexible plant processing practices, consistent with what was observed for the Ongamira Valley.

In sample No. 12, starches of algarrobo (*Neltuma* sp.), maize (*Zea mays*), potato (*Solanum tuberosum*), and bean (*Phaseolus* sp.) were identified, along with phytoliths related to squash (*Cucurbita* sp.), indicating its participation in various domestic activities linked to cultivated resource processing.

Sample No. 13 provides conglomerates of gelatinized starches associated with algarrobo (*Neltuma* sp.), along with epidermal tissues, plant fibers, and phytoliths of the Poaceae family (elongate, blocky, spheroids, and bilobates), with the probable presence of maize phytoliths (wavy-top rondel). This evidence is part of a set of plant processing practices that involved both wild and cultivated resources.

In sample No. 14, starches of wild tubers were recorded, along with potato (*Solanum tuberosum*), bean (*Phaseolus* sp.), and maize (*Zea mays*), in addition to phytoliths related to Cucurbitaceae (*Cucurbita* sp.). This assemblage suggests diversified grinding and the combination of wild and domesticated resources. A compound starch grain, still without taxonomic determination, complements the record.

Consistently, sample No. 15 presents Asteraceae tissues, a sponge spicule, and starches linked to algarrobo (*Neltuma* sp.), potato (*Solanum tuberosum*), maize (*Zea mays*), and wild tubers, in addition to a possible algarrobo pollen grain, reinforcing the interpretation of broad and varied domestic practices.

Finally, sample No. 16 includes algarrobo (*Neltuma* sp.) phytoliths, pollen of the Amaranthaceae–Chenopodiaceae complex, sponge spicules, and crushed and gelatinized starches. This assemblage indicates the processing of plant mixtures that could be linked to the preparation of food and/or fermented beverages.

Table 2
Botanical remains and recovery contexts.

| Site | Sample N° | Recovery context | Botanical findings |
|---|---|---|---|
| Ongamira - ADR | 1 | Fill of an excavated trench | Phytoliths related to Poaceae and starch grains corresponding to wild tubers and algarrobo (*Neltuma* sp.), together with starches associated with potato (*Solanum tuberosum*), squash/pumpkin (*Cucurbita* sp.), bean (*Phaseolus* sp.), and maize (*Zea mays*). |
| Ongamira - ADR | 2 | Stratigraphy | Phytoliths related to Poaceae, together with phytoliths and starch grains of algarrobo (*Neltuma* sp.) and pollen grains possibly associated with this species and the Amaranthaceae–Chenopodiaceae complex. |
| Ongamira - ADR | 3 | Surface collection | Phytoliths related to Poaceae (bulliform, elongate, saddle, and spheroid morphotypes), plant tissue fragments, fibers and vascular elements; circular starch grains and one lepidopteran scale. |
| Ongamira - ADR | 4 | Stratigraphy | Phytoliths related to Poaceae and phytoliths and starch grains of algarrobo (*Neltuma* sp.), accompanied by pollen grains possibly linked to algarrobo and the Amaranthaceae–Chenopodiaceae complex. |
| Ongamira - PNO 5 | 5 | Stratigraphy | Cluster of gelatinized starch grains related to *Zea mays*, starch grain associated with *Phaseolus* sp., Poaceae phytoliths (elongate, bilobate, rondel, and saddle), and one trichome. |
| Ongamira - ADR | 6 | Surface collection | Poaceae phytoliths (elongate, bilobate, rondel, saddle, and spheroid), starch grains related to maize (*Zea mays*) and algarrobo (*Neltuma* sp.)—the latter in the form of a gelatinized cluster—one starch grain from wild tubers showing signs of mechanical damage, and two globular trichomes. |
| Ongamira - LCMN 1 | 7 | Stratigraphy | Poaceae phytoliths (elongate, bilobate, rondel, blocky, and saddle), epidermal tissue, a gelatinized starch cluster related to *Neltuma* sp., one diatom (possibly *Hantzschia amphioxys*), and one broken pollen grain possibly associated with *Neltuma* sp. |
| Ongamira - MDP 1 | 8 | Stratigraphy | One mechanically damaged starch grain of *Neltuma* sp., circular starch grains related to *Condalia microphylla*, and phytoliths linked to Poaceae (bilobate, elongate, and blocky). |
| Ongamira - PNO 1 | 9 | Stratigraphy | Poaceae phytoliths (elongate, blocky, and flabellate), a gelatinized starch cluster related to *Neltuma* sp., mechanically damaged circular starch grains, plant fibers, and dicotyledonous epidermal tissue. |
| Ongamira - MDP 3 | 10 | Stratigraphy | Starch grains related to *Neltuma* sp. and phytoliths linked to the Poaceae family (bilobate, elongate, and bulliform). |
| Ongamira - PNO 1 | 11 | Stratigraphy | Poaceae phytoliths (elongate, blocky, and bulliform), a gelatinized cluster of starch grains related to *Neltuma* sp., damaged starch grains, plant tissues and fibers (epidermal and vascular), starch grain related to an unidentified wild tuber, and pollen grains possibly corresponding to algarrobo and one unidentified. |
| Characato - El Dique | 12 | Surface collection | Starch grains related to maize (*Zea mays*), algarrobo (*Neltuma* sp.), potato (*Solanum tuberosum*), bean (*Phaseolus* sp.), and squash/pumpkin (*Cucurbita* sp.), in addition to Poaceae phytoliths (bilobate and flabellate). |
| Characato - Taller 1 | 13 | Surface collection | Poaceae phytoliths (elongate, blocky, spheroid, and bilobate), a gelatinized starch cluster related to *Neltuma* sp., two broken circular starch grains, epidermal tissue, plant fibers, and diagnostic maize phytoliths (wavy-top rondel). |
| Characato - Cueva 1 | 14 | Surface collection | Phytoliths related to Poaceae (elongate, bilobate, and rondel) and Cucurbitaceae (*Cucurbita* sp.), together with starch grains from wild tubers, potato (*Solanum tuberosum*), bean (*Phaseolus* sp.), and maize (*Zea mays*). |
| Characato - Cueva 1 | 15 | Surface collection | Phytoliths related to Poaceae (elongate, flabellate, and spheroid), Asteraceae plant tissue, one sponge spicule, and starch grains linked to algarrobo (*Neltuma* sp.), potato (*Solanum tuberosum*), maize (*Zea mays*), and wild tubers, as well as one possible pollen grain associated with algarrobo. |
| Characato - Cueva 1 | 16 | Surface collection | Phytoliths of algarrobo (*Neltuma* sp.) and pollen of the Amaranthaceae–Chenopodiaceae complex, together with one sponge spicule and circular gelatinized and damaged starch grains. |

# Morphotypological and Macrofunctional Analysis

Following the proposed methodology, the 16 pieces were subjected to a morphotypological and macrofunctional analysis in order to approach their mode of use and life history. This approach allowed the identification of features linked both to their manufacture and to their function within the tool assemblage. The main techno-morphological characteristics are summarized in Table 3.

Table 3
Morphotypological and macrofunctional analysis of the analyzed artifacts

| Sample N° | Typological Group | Raw Material | Granulometry | Length | Width | Thickness | Primary shape | Whole or broken | Functional Condition | Primary Functions | Modes of Action |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | MH | Granite | 2 | 114,7 | 106,8 | 76,7 | PCOE | W | A | MGPC | PVP |
| 2 | CH/RTF/LAR | Granite | 1 | 99,3 | 72,2 | 32,3 | NH | B | A | GPC | PSD |
| 3 | CH/A | Granite | 2 | 118,77 | 87,05 | 59,46 | PEFE | W | A/P | GPC /S | S/PSD |
| 4 | CH/RTF/LAR | Granite | 1 | 101,9 | 66,5 | 42,1 | NH | B | A | GPC | PSD |
| 5 | C | Granite | 1 | 102,76 | 88,87 | 31,46 | NH | B | P | S | S |
| 6 | CH/H | Granite | 1 | 126,75 | 89,80 | 61,17 | PFC | B | A | GPC /P | PSD/P |
| 7 | H/MH | Granite | 1 | 91,05 | 78,26 | 75 | PCOE | W | A | P | P |
| 8 | CH/H | Granite | 2 | 131,26 | 99,37 | 52,25 | PEFE | B | A | GPC /P | PSD/P |
| 9 | CH | Granite | 2 | 102,41 | 75,5 | 44,42 | PEFE | W | A | GPC | PSD |
| 10 | CH/H | Granite | 2 | 91,62 | 80,71 | 44,63 | PFC | B | A | GPC /P | PSD/P |
| 11 | CH/MH/H | Granite | 1 | 73,80 | 62,23 | 55,29 | PEFE | B | A | MGPC /P | PVP/P |
| 12 | CH | Granite | 2 | 110,3 | 87 | 51,4 | PEFE | W | A | GPC | PSD |
| 13 | CH/H | Granite | 2 | 89,44 | 71,13 | 51,35 | PCOE | B | A | GPC /P | PSD/P |
| 14 | CH/RTF | Granite | 1 | 87,4 | 53,2 | 52,2 | NH | B | A | GPC | PSD |
| 15 | CH/RTF | Granite | 1 | 100 | 62,9 | 42,7 | NH | B | A | GPC | PSD |
| 16 | CH | Metamorphite | 1 | 53,2 | 48 | 24,4 | PEFE | B | A | GPC | PSD |

# Traceological Analysis

Sample No. 1 corresponds to a mortar handstone that shows a scarred surface on its c-plane, with intense abrasion, edge rounding, and generalized polish. On this main plane, deep wear resulting from repeated movement over the mortar is observed, accompanied by upward polish toward planes a and b. Figure 4 – 1 illustrates negative flake scars accompanied by edge rounding, possibly resulting from impacts and friction.

Within the same stratigraphic unit, specimens No. 4 and 2 come from the same stratigraphic unit. The first corresponds to a fractured grinding slab handstone with smoothed and polished surfaces, affected by weathering and thermal alteration that give it a distinctive luster, mainly on its a and b planes. Its rounded edges and greasy patina suggest repeated use in the grinding of organic materials (Fig. 4 – 2). The second specimen, a fragment of a possible fractured *conana*, presents surface smoothing, rounded crystals, and residues accumulated in the interstices. On its main face, well-defined linear features, polish, and crushed crystals are observed, linked to continuous contact with hard materials, allowing it to be interpreted as a passive grinding element (Fig. <link rid="fig4">4</link>–4).

With probable alternate use as an anvil and grinding stone, specimen No. 3, on its b-plane, shows evidence of concentric impacts, while on the opposite side, a-plane, generalized smoothing and intense polish are observed, indicative of repeated use. Microfracturing on crystal edges and generalized damage are illustrated (Fig. 4 – 3).

Meanwhile, sample No. 5 corresponds to a fractured *conana* that presents intense polish and characteristic luster, resulting from prolonged use in grinding activities (Fig. 4–5). On its concave a-plane, flattened crystals, crushed peaks, and organic residues adhered in the interstices were observed, features consistent with a passive surface subjected to repeated friction.

Specimen No. 6 combines evidence of use as a grinding stone and hammerstone. On its a-plane, a fracture resulting from repeated impacts is observed; microscopically, star-shaped crystals and crushed areas are distinguished; while the b-plane shows polishes on the elevated peaks of the microtopography, crystal detachments, and surface flattening (Fig. 4–6), associated with use as an active handstone.

In turn, sample No. 7, of rounded morphology, presents generalized pecking and abrasion across its entire surface, with its c-plane flattened, polished, and with rounded, worn edges. These features suggest prolonged use in grinding activities. Moreover, its a and b planes, with pecking and impact features, would indicate its more evident primary function: percussion. Figure 4–7 illustrates the surface damage.

In specimen No. 8, impacts and fractures are recorded at one of its ends, observable on both a-plane and b-plane, with material detachments associated with use as a hammerstone. Meanwhile, on the b-plane, traces compatible with use as an anvil are observed, while the opposite side (a-plane) presents homogeneous and intense polish (Fig. 4–8) and rounded edges, suggesting secondary use as a grinding stone.

Artifact No. 9 would correspond to a grinding handstone, presenting on its planes generalized surface flattening. However, the greatest intensity is shown on the b-plane, with a micro-crushed surface featuring truncated peaks and intense luster associated with polish (Fig. 4–9) and the accumulation of

organic residues, characteristic of grinding activity. The micaceous composition of the granite reinforces the surface luster.

Likewise, sample No. 10, interpreted as a grinding slab handstone with possible secondary use as a hammerstone, presents surface smoothing (Fig. 4–10), crystal detachment, and crushed peaks on its a-plane. Meanwhile, on the b-plane, a fracture attributable to percussion impact was observed at one of the ends. Its plano-convex morphology, together with the presence of negative flake scars, broken crystals, polishes, and generalized abrasion, suggests versatile use in different tasks.

On the other hand, specimen No. 11 presents three smoothed planes (a, b, and c), with one fractured end and another (d-plane) impacted, illustrating concentric fractures and localized polish. It combines evidence of use as a *conana* handstone and hammerstone. The flat surfaces exhibit luster resulting from the flattening and smoothing of peaks, with generalized and multidirectional striations (Fig. 4–11), indicating combined use in grinding, in addition to percussion.

Continuing with the samples from Characato, five granite grinding and percussion artifacts recovered from surface contexts were analyzed, coming from the sites Cueva 1 (n = 3), El Dique (n = 1), and Taller 1 (n = 1). In general terms, the instruments present evidence of repeated use, differential wear, and various traces of thermal alteration, suggesting a prolonged use-life and exposure to variable environmental conditions.

Regarding sample No. 12, a use combining evidence of a grinding slab handstone reused as a hammerstone is interpreted. The piece presents on its a and b planes surface smoothing, crushed and flattened peaks, as well as negative detachment scars and rounded edges (Fig. 4–12). At one end of the a-plane, a fracture resulting from impact is distinguished. On the frontal plane of the fracture, multidirectional striations and large negative flake scars are observed, while the ends exhibit crushing produced by direct blows. Generalized polishes and adhered residues indicate intensive and versatile use, alternating between grinding and percussion tasks.

Specimen No. 13 was interpreted as a multifunctional instrument, possibly used as a hammerstone and grinding stone. It presents luster from peak truncation on both planes (a and b), along with whitish residues adhered mainly on the c-plane, probably resulting from contact with dry mineral or plant substances. In sectors of planes a and b, well-developed polishes with multidirectional striations are observed (Fig. 4–13), indicative of repeated use in fine grinding or final crushing of plant materials.

Regarding sample No. 14, it corresponds to a grinding slab handstone made of coarse-grained granite, which presents evident signs of thermal fracture and edge damage. The crystals show, on all its planes, peak truncation and, in some sectors, a metallic luster resulting from fluid action, mainly on the thermally altered b-plane. The surface exhibits generalized polish (Fig. 4–14) and adhered microscopic residues, while on the less affected opposite face (a-plane), micro-detachments of crystals and spalls are observed, along with incipient polishes.

Next, artifact No. 15, also a grinding slab handstone, presents a lighter coloration and smoothed surfaces. Multidirectional striations, crushed peaks, and truncated edges are observed, with polishes concentrated on the longitudinal ends of the planes (Fig. 4–15), evidence of repeated back-and-forth movements. On the b-plane, short, grouped striations are associated with dark residues linked to thermal alteration processes, while the a-plane, more weathered, shows generalized crushing that reinforces the idea of oscillating movement during grinding. Secondary use as a hammerstone cannot be ruled out, due to the fractures present at its ends.

Finally, sample No. 16 corresponds to a grinding slab handstone made of microcrystalline rock, which exhibits surface smoothing and generalized crushing (Fig. 4–16). The c-plane is microfractured, with bright, crushed peaks, while the matrix shows sectors with isolated polish, resulting from prolonged friction on materials of different hardness. In turn, the a-plane presents repeated contact or friction wear.

## DISCUSSION

At the archaeobotanical level, the differences and similarities between the assemblages from both regions reinforce the idea of a diverse and complementary management of plant resources. In Ongamira, artifacts associated with Late Holocene stratigraphic contexts present microremains from a wide variety of plants, both cultivated and wild: maize (*Zea mays*), bean (*Phaseolus vulgaris*), potato (*Solanum tuberosum*), squash (*Cucurbita* sp.), algarrobo (*Neltuma* sp.), piquillín (*Condalia microphylla*), and wild tubers. The presence of these taxa, together with Poaceae phytoliths (elongate, rondel, saddle, and bilobate forms), suggests multifunctional grinding activity, oriented toward the processing of diverse food products.

Much of the analyzed sample comes from occupation moments near or after 1900 BP, although the chronology of piece 1—which comes from a trench fill from excavations conducted by Menghin and González in the 1950s (Menghin and González 1954)—is unknown. Samples 3 and 6 were collected from surface contexts and, according to the anthropogenic activities carried out at the site over the last 50 years, could correspond to surface levels and later occupation moments at the site (Cattáneo and Izeta 2016). The remaining pieces recovered from the ADR site (2 and 4) come from stratigraphic excavation contexts and are located below a date of 1823 ± 20 BP. In both pieces, the presence of pollen grains associated with the Amaranthaceae–Chenopodiaceae complex was recorded, a taxon already studied at the macroremain level by Romanutti (2022) for the interior of the ADR rock shelter during a time span between *ca.* 4500–3000 BP.

For the PNO 1 site, both pieces come from levels associated with the date 1905 ± 20 BP (YU-7746) (Izeta et al. 2021). Notably, piece 5 from the PNO 5 site comes from a level dated to 942 ± 20 BP (YU-7749) and is the only one with a precise chronology that shows evidence of processing of *Zea mays* and *Phaseolus* sp., both cultivable species. The remaining pieces, given that they come from fill or surface contexts, do not allow us to obtain a more precise chronology for the processing of these plants.

Regarding the pieces from open-air sites (MDP 1, MDP 3, and LCMN 1), their contextual association with ceramic technology allows us to associate them with an occupation near or after *ca.* 1900 BP, when the earliest date for ceramic technology at the PNO1 site was obtained (Robledo and Gasparotti 2021). Furthermore, both MDP1 and MDP3 are flat sectors near watercourses (50 meters away) and each is associated with granite mortar supports (Robledo 2020). This contextual information, together with the evidence of processing of wild plants with edible fruits (*Neltuma* sp. and *Condalia microphylla*), suggests an activity more focused on the use of woody resources from the lower valley sector, in contrast to the rock shelter sites (ADR, PNO1, and PNO5) where grinding of both wild and cultivated species is observed.

In Characato, where surface contexts and thermally altered artifacts predominate, the microremains point to a similar composition, but with a higher frequency of morphotypes associated with domesticated crops, especially maize (*Zea mays*) and bean (*Phaseolus vulgaris*), accompanied by plant fibers and cucurbit phytoliths. This trend could be related to differences in use and discard contexts, as well as specific modalities of space occupation, possibly associated with seasonal stays or food preparation and transformation activities, such as the production of flours or fermented beverages (*patay* or *chicha*).

In both assemblages, the record of algarrobo (*Neltuma* sp.) starches is especially significant, given its central role as an energy resource and its wide availability in the mountainous landscape. The presence of its microremains on artifacts of different functions (handstones, *conanas*, and mortars) suggests that its processing constituted a sustained practice over time, articulating pre-existing technical traditions with the incorporation of domesticated species. In the particular case of Ongamira, macroremains of *Neltuma* sp. were identified in a span of *ca.* 3000–3600 BP for the ADR site by Romanutti (2022). This pattern becomes more relevant when considering that algarrobo has a low representation in the anthracological assemblage corresponding to the period *ca.* 4500–900 BP, where it appears among the least frequent taxa as firewood (Robledo 2021).

These results fit into a regional pattern widely documented for central and southern Argentina. In San Luis province, sites such as Arroyo Saladillo, Alero Dupuy, and La Vertiente have recorded the joint presence of cultigens (maize, bean, and squash) together with wild grasses, evidencing mixed subsistence strategies similar to those observed here (Borgo et al. 2022; Lalinde Aguilar et al. 2018). Within this framework, the centrality of algarrobo emerges as a regional constant: its processing has also been documented at Punta Odriozola (Río Negro), suggesting an extensive exploitation of its pods in the Southern Cone at least since the Middle Holocene (Ciampagna et al. 2020).

For Córdoba, the results presented here reinforce previous interpretations regarding the complementary use of wild and cultivated plants. In sites from the Punilla valley, such as C. Pun. 39, an archaeobotanical assemblage composed of maize, beans (*Phaseolus vulgaris* and *P. lunatus*), squash, as well as wild fruits including algarrobo and chañar has been recorded (Medina et al. 2009; López 2017). Consistently, the identification of piquillín (*Condalia* sp.) in the analyzed samples coincides with macrobotanical records from sites in northern Córdoba, such as Quebrada Norte 7, where this wild resource has been noted as recurrent (López 2017). Likewise, the presence of potato (*Solanum tuberosum*) has been documented in northern sectors of the province, supporting the findings obtained for Ongamira.

The results obtained from the macroscopic and microscopic analysis of the granite artifacts allow us to infer that the studied assemblages correspond to instruments with intensive use trajectories, characterized by a combination of grinding, percussion, and functional reuse. The recurrence of generalized polishes, intense abrasion, peak truncation and flattening, multidirectional striations, as well as the accumulation of residues in interstices, constitutes a consistent indicator of prolonged grinding activities, probably associated with the repeated processing of organic and/or mineral materials. In several specimens, these traces are articulated with clear evidence of impact, such as percussion fractures, negative flake scars, crushing, and spalling, reinforcing the idea of instruments with multiple functions and extended use over time.

In the assemblage from Ongamira (samples 1–11), a wide functional diversity is recorded, with instruments interpreted as mortar handstones, grinding slab handstones, *conanas*, and pieces with alternate use as anvil/handstone, in addition to specimens where percussion appears as a primary or secondary function. In this sense, the coexistence of active and passive surfaces with different degrees of wear suggests that the instruments were used repeatedly. This dynamic is expressed, for example, in pieces with intensely polished planes and others with impact damage, evidencing alternation of technical gestures (back-and-forth grinding, crushing, direct blows) and the use of the same support for different tasks.

Meanwhile, the Characato assemblage (samples 12–16), recovered from surface contexts, shows a similar trend, although with particular interpretative weight regarding thermal alteration, weathering, and luster associated with post-depositional processes. However, even in these cases, the recorded use-wear (especially polishes, striations, and friction-related spalling) allows us to sustain repeated use in grinding and, in several specimens, reuse as hammerstones. The presence of multifunctional instruments in this assemblage, added to the recurrence of traces compatible with back-and-forth movements, reinforces the interpretation of technological practices where granite artifacts were central components of processing activities.

Regarding raw materials, it was considered that coarse-grained rocks present lower reflectivity and more irregular fractures than fine-grained ones, which generates less bright polishes. In this sense, special attention was paid to differentiating between the natural luster of mineral crystals and that generated by polishing processes. Likewise, it was considered that use-wear formation on heterogeneous coarse-grained raw materials is usually slower than on finer-grained rocks, such as chalcedonies or siliceous rocks (Leipus 2006; Leipus and Mansur 2007; Mansur 1999; Pal 2015).

From a functional perspective, the wear patterns observed on the grinding artifacts correspond to prolonged friction processes that, as experimental studies indicate, involve different surface alteration mechanisms (abrasive, adhesive, fatigue, and tribochemical) (Teer and Arnell 1975). In the grinding of grains such as maize, continuous contact between the surfaces of the handstone and base produces heat, odor, and progressive polish, initially localized at the points of greatest friction and then extended over the smoother areas. Friction generates cones, scales, and pits when adhesive microunions between crystals break, and with sustained use, the resulting flour fills the interstices, obstructing the original roughness and giving rise to brighter and

more leveled surfaces. These processes coincide with the polishes and smoothed fields documented in the analyzed pieces, where the combination of mechanical wear and accumulated residues produces reflective surfaces. In this sense, polish traces can be interpreted as resulting from both additive processes (accumulation of tribochemical residues) and physical wear, in agreement with the proposals of Anderson (1980), Unger-Hamilton (1984), and Hayden and Kamminga (1979).

In both assemblages, the presence of instruments with intense wear and multifunctionality suggests a prolonged use-life, in which the artifacts were subjected to successive episodes of use, refurbishment, and functional reorientation. This pattern can be interpreted as a strategy of technological optimization, consistent with the heavy and durable nature of these instruments. The variability of traces and the alternation between active/passive functions also allow us to infer a diverse repertoire of processing activities, where grinding, crushing, and percussion tasks were combined, possibly related to food preparation and the reduction of hard materials, characteristic of lithic knapping. These features are recurrent in other artifact assemblages from the region, where similar results have been obtained (Borgo et al. 2022).

Finally, the results reinforce the value of integrating microscopic use-wear analysis in the study of granite artifacts, as it allows for more precise discrimination between surfaces altered by weathering/thermal alteration and those modified by anthropogenic use, as well as identifying wear patterns linked to specific technical gestures. Together, the study contributes to expanding knowledge about grinding and percussion technology in Late Holocene contexts, highlighting the role of these instruments as highly versatile artifacts within regional technological systems.

Considered in their totality, these data allow us to maintain that Ongamira and Characato were part of a social landscape characterized by a mixed economy, in which the incorporation of cultigens did not imply the abandonment of gathering, but rather its integration into strategies of high mobility and intensive use of mountain resources, particularly high-value wild species such as algarrobo.

The spatial and contextual distribution of the artifacts reinforces this interpretation. In Ongamira, grinding instruments were found both in rock shelters with evidence of prolonged occupations associated with combustion structures and deposits of organic remains, as well as in open-air spaces associated with other grinding structures (e.g., MDP1 and MDP3) and with the presence of pottery technology (Robledo and Gasparotti 2021). This suggests domestic and repeated use of space both over time and in carrying out various activities in different sectors of the valley. In Characato, in contrast, findings at open-air sites such as El Dique and Taller 1 indicate processing activities possibly linked to brief stays or seasonal work spaces, where grinding was integrated into other productive tasks.

In this sense, the continuity observed in certain technical practices over time can be interpreted as the materialization of durable dispositions, that is, as the archaeological expression of a *habitus* that structures and reproduces socially shared ways of doing (Bourdieu 2007). The recurrence of certain technical gestures, raw material choices, use modalities, as well as certain domestic and wild resources, suggests that the knowledge involved in the production and use of artifacts was not limited to individual or contingent decisions, but was transmitted generationally as part of an embodied *savoir-faire* (Kelly 1983; Ericson 1984; Schiffer and Skibo 1987; Ingold 1990; Lemonnier 1992; Bamforth and Bleed 1997). Regional studies for the Late Holocene, such as those conducted by Cattáneo et al. (2016b, 2022), evidence technological stabilities sustained over millennia, reflected both in repeated practices of hafting with local resins and recurrent point designs, as well as in the systematic use of quartz micro-wedges for fracturing bone elements. These persistences do not imply an absence of change, but rather the reproduction of relatively stable technical schemes that operate as frameworks for action, within which populations adjusted their strategies in response to environmental variations, demographic changes, or interregional interactions, while maintaining cores of continuity in their technological organization.

In synthesis, the convergence between techno-morphological, functional, and microbotanical analyses provides a consistent and articulated line of evidence for understanding the persistence and resignification of technological practices linked to plant processing among hunter-gatherer groups and the first food-producing societies of central Argentina. Microscopic traces, plant residues, and wear patterns not only allow us to recognize the technical actions involved in grinding, but also to reconstruct the ways in which highland communities articulated technical knowledge, local resources, and food practices within the framework of flexible and adaptive subsistence strategies.

## CONCLUSION

The analysis of granite artifacts from Ongamira and Characato allowed the identification of diagnostic traces linked to grinding and percussion, evidencing repeated use, multifunctionality, and reuse, with prolonged use-life trajectories. The integrative approach, which combined archaeobotanical, techno-morphological, and functional analyses, made it possible to reconstruct both the manufacturing and use processes as well as the social and economic practices associated with plant processing in the central region of Argentina during the Middle and Late Holocene.

From an archaeobotanical perspective, the identification of plant microremains (mainly phytoliths and starch grains) provides direct evidence of the species selected and processed. The records reveal a notable diversity that combines domesticated plants (such as maize (*Zea mays*), bean (*Phaseolus vulgaris*), squash (*Cucurbita* sp.), and potato (*Solanum tuberosum*) with wild resources, including algarrobo (*Neltuma* sp.), piquillín (*Condalia microphylla*), and wild tubers. This coexistence of wild and cultivated species suggests the persistence of mixed subsistence strategies, where gathering and processing of local resources continued to be relevant practices even during times of cultigen incorporation. Furthermore, it allows for greater taxonomic variability and strategies for the use of wild plant resources already reflected by high taxonomic diversity in use as firewood (Robledo 2021) and by the presence of plant macroremains (Romanutti et al. 2026).

In Ongamira, the typological and functional diversity of the instruments suggests a technologically complex assemblage, where mortar handstones, grinding slab handstones, *conanas*, and anvils/hammerstones were part of recurrent processing practices. In Characato, despite the weathering and

thermal alteration recorded in some specimens, microscopic traces allow interpretations consistent with prolonged grinding and reuse as hammerstones.

It is worth noting that this study constitutes the first systematic investigation of this type of artifact for the region, expanding knowledge about the variability of strategies adopted by highland populations throughout the Late Holocene. Microscopic observations, complemented by experimental studies on adhesive and abrasive wear mechanisms, allowed the recognition of the complexity of the tribological processes involved in the generation of polishes and micro-wear, highlighting the role of heat, friction, and the accumulation of fine residues in the progressive modification of grinding surfaces. These wear patterns not only inform about the physical processes involved in grinding, but also allow inferences about modalities of repeated use, variable work intensities, and technical decisions aimed at maximizing the use-life of the instruments.

Likewise, the spatial and contextual distribution of the artifacts shows that grinding and plant processing activities were carried out in a variety of spaces: from shelter or residential areas (such as the rock shelters of Ongamira) to open or seasonal sectors (such as El Dique and Taller 1 in Characato; in addition to MDP 1, MDP 3, and LCMN 1 in Ongamira). This contextual diversity reflects a dynamic occupation of the mountain landscape and a continuity in technological strategies adapted to different activity areas.

In this sense, the integrative approach adopted constitutes a robust analytical pathway for examining the interrelationships between technology, environment, and subsistence strategies. By integrating microscopic and contextual scales, this approach allows access to everyday dimensions that are hardly perceptible in the archaeological record, offering a more complex and situated perspective on food practices and forms of interaction between humans, plants, and rocks in the past.

In general terms, the study shows that granite artifacts should not be understood as single-function artifacts, but rather as versatile components, subjected to functional alternation, maintenance, and reorientation. This pattern is linked to technological strategies of intensive use of durable supports and provides relevant evidence for discussing the economic and domestic practices of the populations that occupied both sectors.

## Declarations

*Conflicts of interest and funding:* The authors declare that they have no conflict of interest relevant to the content of this article.

# Author Contribution

CB: Writing – review and editing, Writing – original draft, Methodology, Formal analysis, Data management, Conceptualization. AT: Writing – review and editing, Writing – original draft, Methodology, Formal analysis, Data management, Conceptualization. AR: Writing – review and editing, Writing – original draft, Formal analysis, Conceptualization. RC: Writing – review and editing, Project management, Research, Fundraising, Conceptualization, Translation.

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## Figures

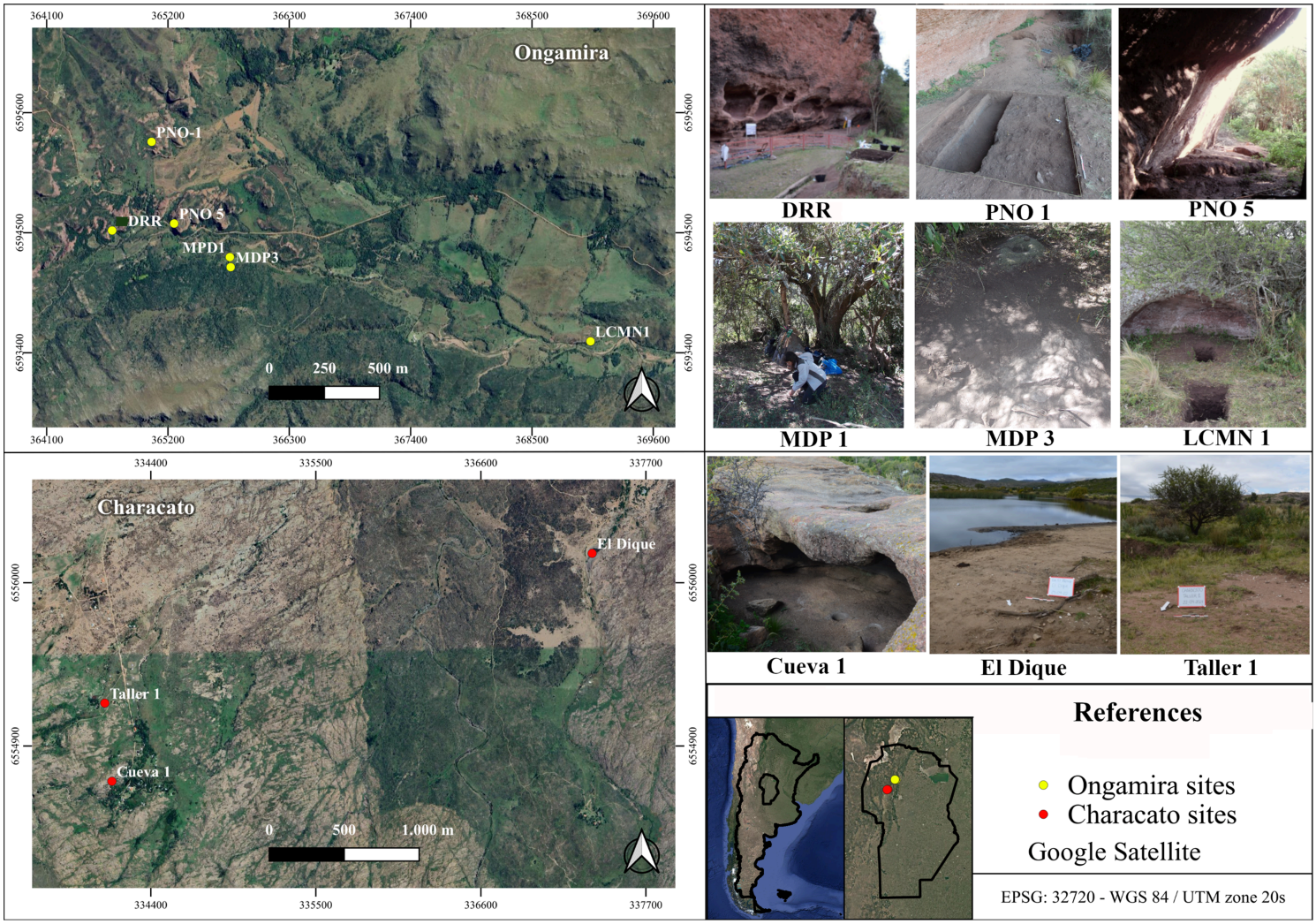


Figure 1

Study area and sample provenance sites: Ongamira and Characato, Córdoba, Argentina

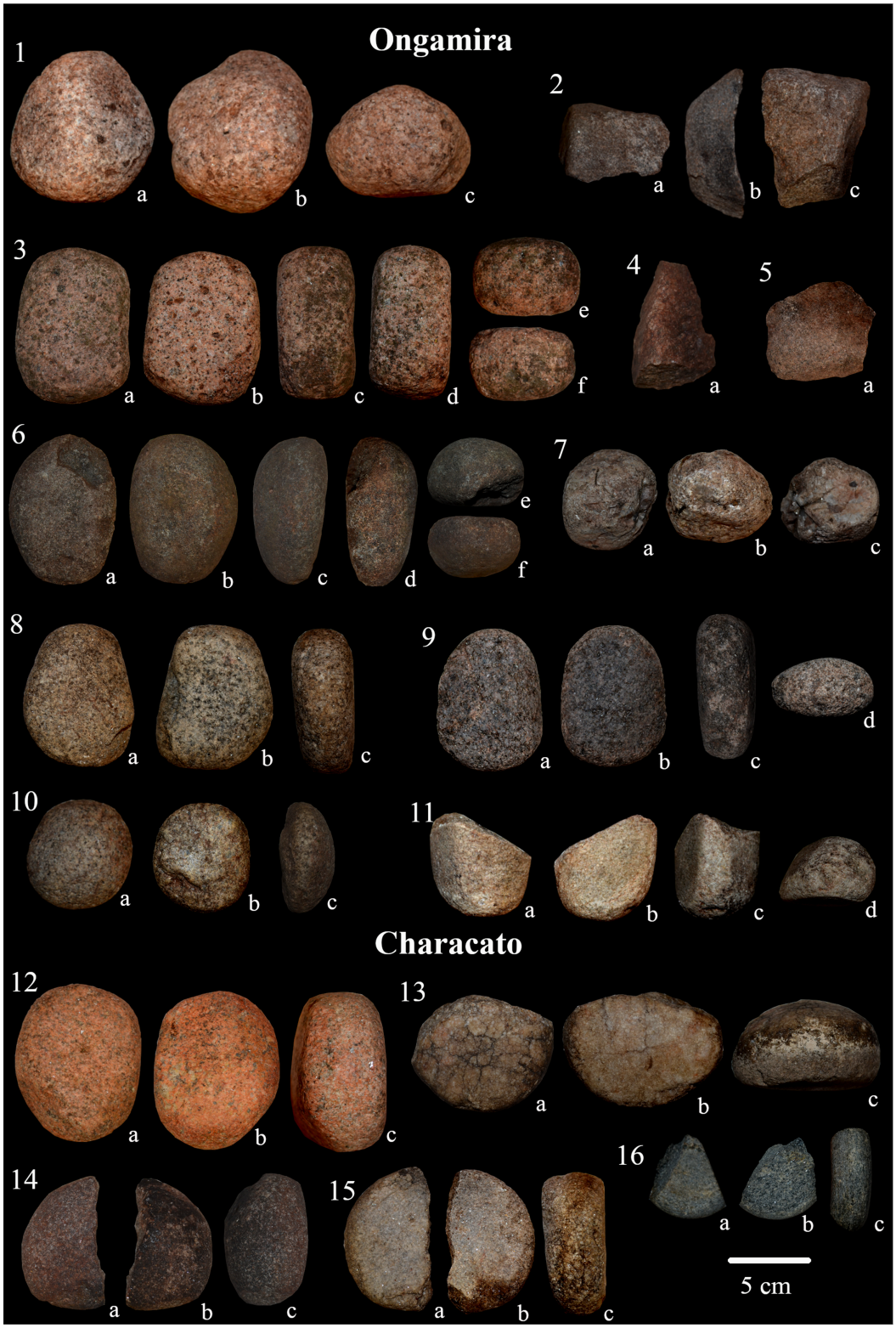



Figure 2

Granite rock artifacts analyzed, recovered from the assemblages of Ongamira (1–11) and Characato (12–16). Letters (a–f) indicate the different views of each piece. Scale: 5 cm

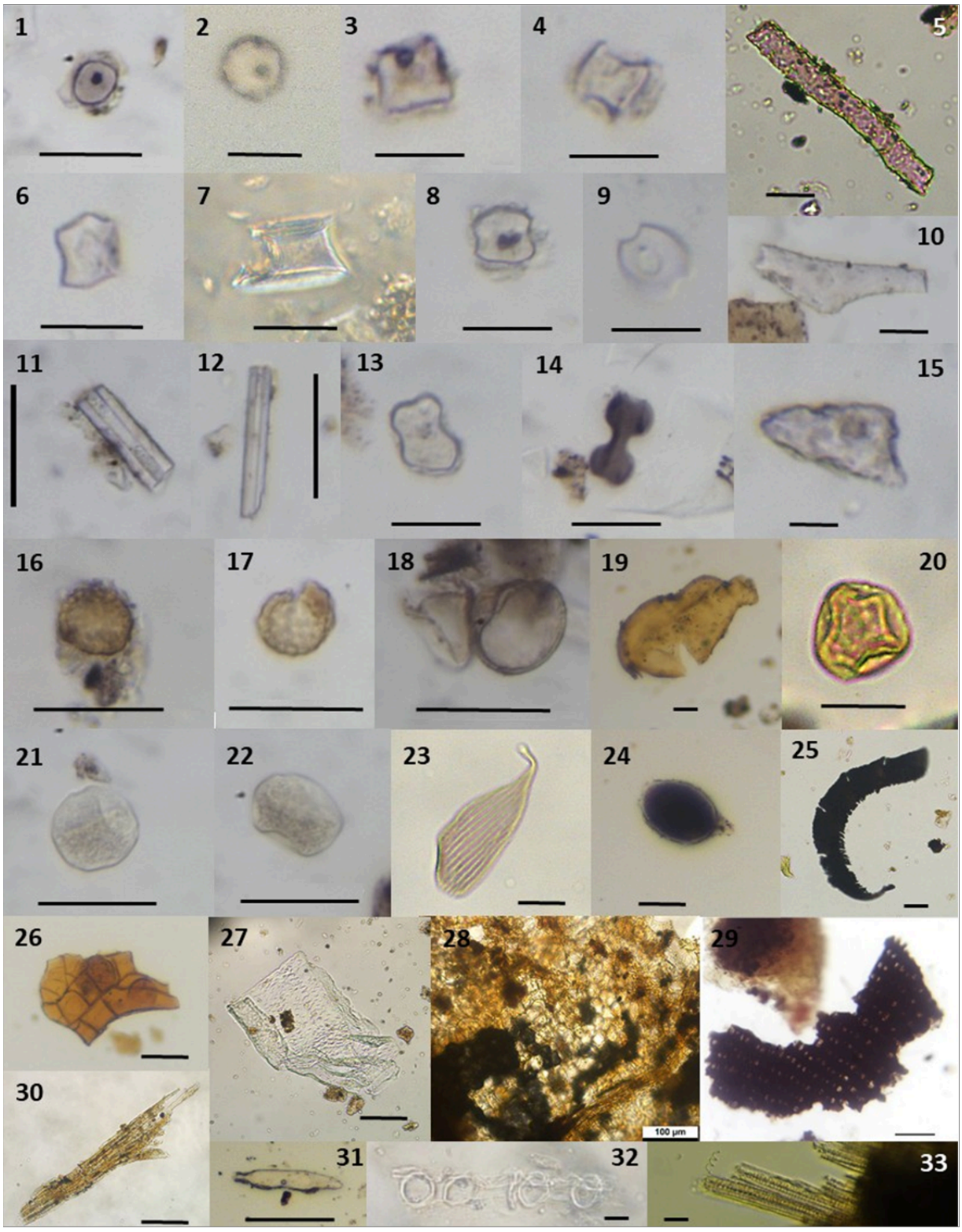



Figure 3

Identified microremains in the analyzed samples: 1–2, psilate spheroids related to *Neltuma* sp. (sample 15 and 6); 3, wavy-top rondel morphotype related to *Zea mays*(sample 15); 4, 6–7, rondels (sample 1, 2 and 9); 5 and 10, elongate forms (sample 9 and 1); 8–9, saddle forms (sample 14 and 1); 11–12, sponge spicules (sample 16 and 2); 13–14, bilobate forms (sample 1and 15); 15, flabelate form (sample 1); 16–17, pollen grains from the Amaranthaceae/Chenopodiaceae complex (Artifacts 15 and 16); 18, pollen grains (sample 15); 19–22, pollen grains (sample 7, 11and 2); 23, lepidopteran wing scale (sample 11); 24, chrysophyte stomatocyst (sample 6); 25, possible insect cuticle fragment (sample 9); 26, dicot leaf epidermis fragment (sample 7); 27, pitted tracheary element (Artifact 9); 28, dicot mesophyll fragment (sample 11); 29, perforated Asteraceae plate (sample 2); 30, plant fibers (sample 11); 31, diatom possibly corresponding to *Encyonopsis microcephala* (sample 7); 32, conductive element (sample 14); 33, tracheids (sample 3). *Scale: 20 µm*

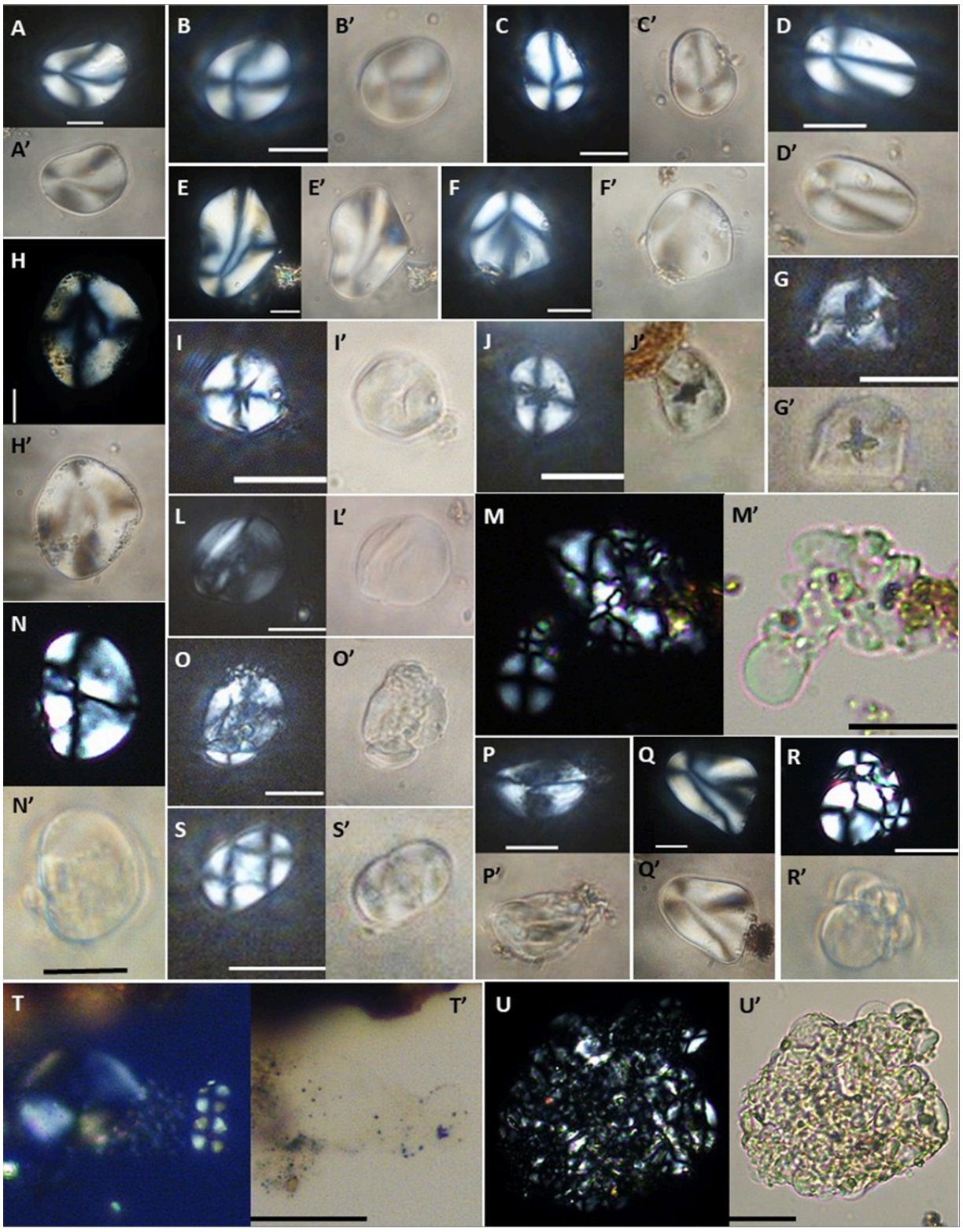



Figure 4

Starch grains identified in the lithic artifacts: A–A', oval starch grain corresponding to an unidentified wild tuber (sample 11); B–B' and C–C', starch grains related to Cucurbitaceae (sample 1); D–D', oval starch grain associated with S*olanum tuberosum* (sample 12); E–E' and F–F', starch grains linked to unidentified wild tubers (sample 1); G–G', polygonal starch grain characteristic of *Zea mays* (sample 5); H–H', starch grain corresponding to an unidentified wild tuber (sample 6); I–I' and J–J', starch grains attributable to *Zea mays*(sample 6 and 15); L–L', starch grains related to *Phaseolus* sp. (sample 5); M–M', circular and polygonal starch grains related to *Neltuma* sp. (sample 9); N–N', starch grain attributable to *Phaseolus* sp. (sample 5); O–O', circular starch grains with evidence of crushing (sample 9); P–P', oval starch grain showing signs of gelatinization (sample 2); Q–Q', starch grains corresponding to *Cucurbita* sp. (sample 12); R–R', circular starch grains related to *Neltuma* sp. (sample 11); S–S', compound starch grain of unidentified origin (sample 4); T–T', circular starch grains consistent with *Condalia microphylla* (sample 8); U–U', gelatinized starch grains related to *Neltuma* sp. (sample 11). *Scale: 20 µm*

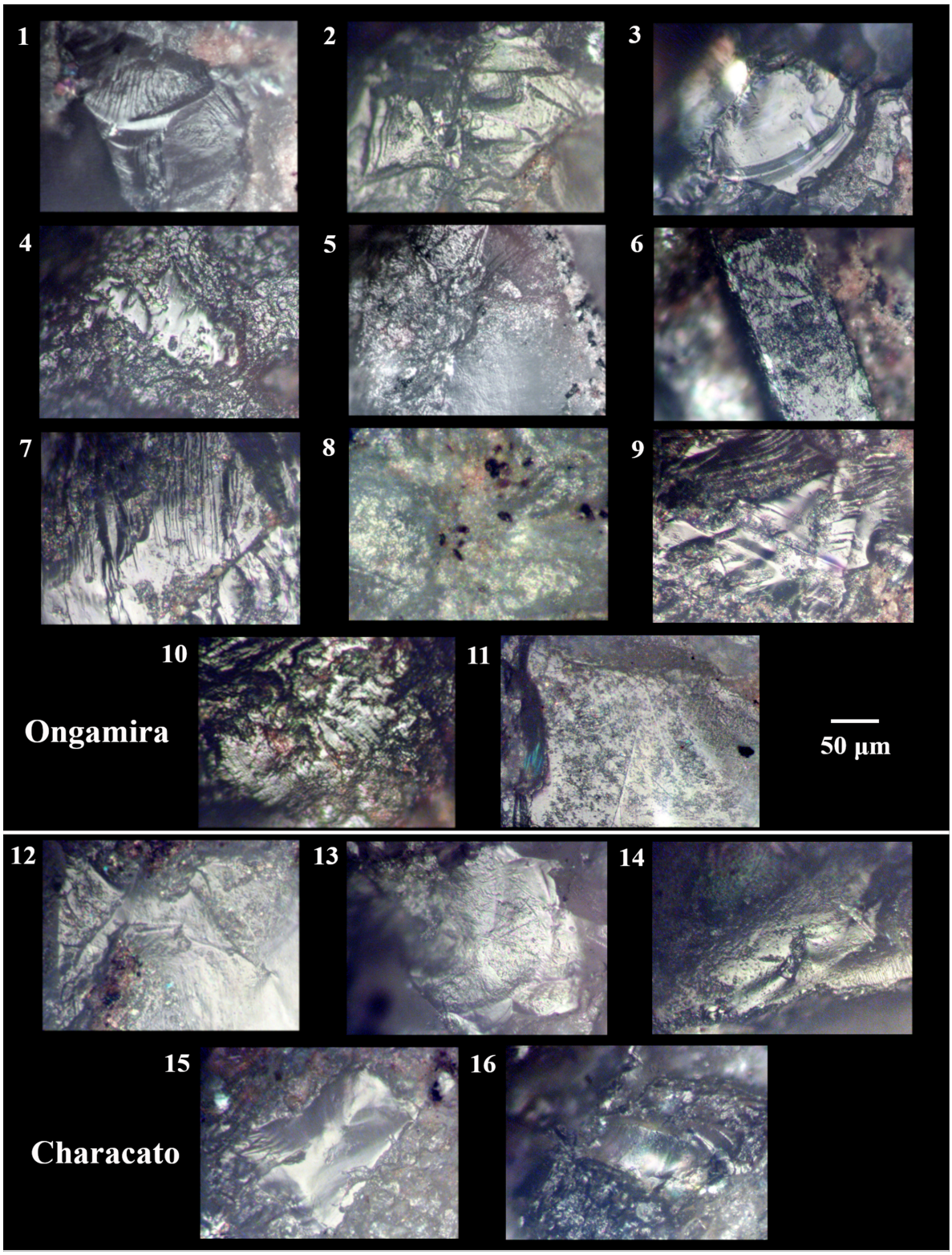



Figure 5

Microphotographs of use-wear and surface alterations on granite artifacts linked to grinding and percussion from Ongamira (1–11) and Characato (12–16). Ongamira: (1) negative flake scars, intense abrasion, edge rounding, and polish; (2) surface smoothing, rounded crystals, polish, and crushed crystals; (3) impact traces and intense polish; (4) smoothed/polished surfaces and thermal alteration; (5) intense polish and residues in interstices; (6) impact fractures and polish on elevated peaks; (7) grinding features (abrasion and polish) and percussion features (pecking and impacts); (8) surface smoothing; (9) micro-crushing, truncated peaks, and organic residues; (10) polishes, negative flake scars, and fractures; (11) multidirectional striations and localized polish. Characato: (12) smoothing, negative detachment scars, multidirectional striations, and impact fractures; (13) polishes and multidirectional striations; (14) generalized polish and edge microfractures; (15) polishes at ends and microfractures; (16) smoothing, crushing, and microfractures. Scale: 50 µm