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Stones in Context. A Multidisciplinary Approach to Understanding the Manufacture and Use of Roberto Amador lithic artifacts, Chontales-Nicaragua

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ABSTRACT

The present research seeks to make an approach to the understanding of the Roberto Amador site located in the region known as MRV (Mayales River Valley), in the department of Chontales, Nicaragua, through the study of the lithic assemblage. The research sought to approach the strategies of lithic production and use patterns of the lithic material from 3 different perspectives. The first consisted of a technological analysis which sought to identify the lithic reduction sequences present at the site, as well as to characterize each of the manufacturing stages present. In this regard, it was possible to clearly identify the presence of two reduction sequences: first, bifacial shaping and, second laminar reduction sequence. A third reduction sequence (discoid exploitation) were identified but its low frequency did not allow an in-depth study. The second was a statistical analysis which sought to explore the technological variables characterized in the lithic assemblage, in order to search for different links between them to deepen the technological analysis. Finally, an analysis of use wear was conducted with an experimental program that served as a framework of reference to analyze a sample of the lithic assemblage from the Roberto Amador site.

The results of this thesis allowed us to deepen our understanding of the Mayales River valley inhabitants, identifying patterns of use and technological strategies adopted by these groups for their different economic processes. This information was compared with different research made in the area, corroborating certain concepts regarding this prehispanic groups and also generating new hypotheses and questions about them.

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Por todo, te agradezco profundamente mamá.

Por ti, mi vida entera.

Te amo.

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1 Introduction

The research presented in this manuscript reports the development and implementation of several methodologies focused on the study of lithic artifacts from the Roberto Amador archaeological site, located in the Chontales region of Nicaragua. The aim was to carry out a multidisciplinary analysis of this lithic collection in order to create a framework capable of generating different types of data, seeking to obtain results that would allow their integration at different scales of analysis. For this purpose, the following were carried out: *technological analysis*, focused mainly on the study of raw material and procurement, the identification of the technological characteristics of the pieces studied, and the study of the technological trends; *statistical analysis,* which sought to integrate and explore the technological characteristics, in order to perform a more detailed technological analysis; finally, an *analysis of use wear* was carried out on a representative sample of the lithic collection, which was accompanied by the development of an experimental program, in order to determine the patterns of use of the pieces of this collection. The incorporation of various analytical scales in this research was driven by a singular goal: to construct a robust and resilient framework for interpreting this lithic assemblage.

This research took as a study sample the lithic collection recovered within the framework of the PRISMA project ("Finca Santa Matilde Interdisciplinary Project"). This project has had several preliminary fieldworks, and it was not until 2018 when different geoarchaeological and archaeological surveys were carried out, as well as the excavation of 3 stratigraphic pits of 1x1m, along each level of the alluvial terrace where the archaeological site Roberto Amador is located. The present investigation only took as object of study a sample of the lithic collection of excavations No. 2 and 3. According to the initial geoarchaeological data, this site had a late pre-Hispanic occupation located between 900-1250 AD. The PRISMA project, led by archaeologist Irene Torreggiani, is part of her doctoral research and has had the support of several people, including the initial lithic classification work carried out by Samuel. This project seeks to identify the influence and adaptive changes that the groups that inhabited this terrace had in relation to the water tributaries and their management.

Finally, this work sought to deepen the understanding of the lithic technology of the Chontales region (more specifically in the Mayales River Valley-MRV-), which has been the subject of intermittent archaeological interest. This region has the particularity of presenting superficial lithic collections (remains of laminar productions, bifacial instruments, projectile points, polished axes, among others) throughout the MRV area, denoting a complexity in the manufacture of these implements. The study of this area takes on greater relevance if we consider that there have been few studies focused on this subject.

2 Archeological context of Roberto Amador

2.1 Nicaraguan archaeology

In general terms, pre-Hispanic archaeology in Nicaragua has had few systemic studies focused on an exhaustive examination of the material culture found on the surface. Most of these projects took place in the Pacific and North of the country. And as Donner et. al, (2015) reflects, it is important to develop new research in the same areas and in new ones, since the interpretations of the pre-Hispanic past continue to be based on the ideas established by ethnohistory, chronicles of conquerors and priests (mainly Jesuits), making this interpretation lack empirical support (Arteaga, 2017).

The history of archaeological research in Nicaragua has been defined by GORIN (2010), in three different phases from the different approaches given by researchers during the last two centuries. The first research corresponds to the second half of the nineteenth century, which is mainly described by travel chronicles, which describe both the landscape and the different human groups that inhabited the area. These chronicles also present the location of some archaeological sites located on some islands and along the Pacific coast of Nicaragua (Bransford, 1881).

Figure 1 Archaeological area of the Gran Nicoya. From Wikipedia.

The next phase of research developed in Nicaragua is located in the twentieth century and is characterized by the beginning of the systematization of the archaeological records found to give a chronological order to this part of Central America. The chronological definition from monumental presence (Lothrop, 1921) or discussions about the different chronological phases from different decorative styles and ceramic manufacture (Arteaga, 2017) begin to take place (Gorin, 2010). From this background, subsequent studies would be oriented towards the delimitation of cultural areas, exploring their attributes and connections with adjacent regions. The first effort of this nature was led by G. Willey in 1958, raising questions about the cultural and chronological correlations between South America, Central America, and what P. Kirchhoff (1943) identified as Mesoamerica.

The last period begins with the creation of a special issue of the magazine *Vínculos*, published by the National Museum of Costa Rica in 1994 (Gorin, 2010). This volume compiles the results of the most outstanding research related to the Gran Nicoya (macro region that also includes part of the current region of Chontales and where the Roberto Amador site is located-Figure 1).For the first time, publications addressing the archaeology, linguistics and ethnohistory of this region are brought together, allowing a comprehensive discussion of the concept of Greater Nicoya, and incorporating information from surrounding areas. This publication clearly marks the predominant focus in Nicaraguan archaeology: the southern limit of Mesoamerican influence.

These new works would give way to what became known as the Great Nicoya debate. This debate would seek to argue that the cultural limits of this large area did not have to be rigid, and also to affirm that possibly this region could have belonged to a large cultural area defined as an intermediate area (Hoopes, 2012; Lange, 2004).

2.2 Archaeology of the Chontales region – Nicaragua.

While the major area of exploration for archaeologists interested in Nicaragua was the Pacific, alternatively in the middle of the last century, began to study the region of Chontales (Figure 2) and its surroundings, where some work was carried out focused on the study of monumental statuary, tombs and different mounds. The first reports on the archaeology of Chontales are due to the Austrian explorer E. Friedrichsthal, who in 1839 reported in one of his diaries and took back to Austria a statuette associated with what was called a tomb (Geurds & Terpstra, 2013). Similarly, Boyle (1866) also reported how in the region there were different statuettes related to stone constructions and mounds (Geurds & Terpstra, 2013).

Later and more systemically, Sequeira (1942) (in Arteaga, 2017), notes a series of burials in the Chontales region consisting of stone or stone mounds with earth. He proposes a relationship of these rocks with nearby water sources. Likewise, the author states that the larger tombs tend to resemble "primitive pyramids" (Arteaga, 2017), which were 9 to 12 meters high with steps. These structures were located in Juigalpa, a city within the Chontales region.

Subsequently, in the mid 70's, the first archaeological investigations began. R. Magnus studied and recorded different sites along the Pacific coast and around Lake Nicaragua, including the region of Chontales. This research had a great impact on the understanding of the relationships of this area, as Magnus concluded that these areas had local cultural developments and not as annexes or satellite cultures of the great Central American cultures (Arteaga, 2017).

One of the theses that emerged from Magnus' early work was the research of (Gerstle, 1976), who focused on the analysis of lithic instruments from a test pit at the Sabana Grande site. The author concludes that, based on a macroscopic analysis (lower approach) of the identified forms, the activities carried out by the lithic artifacts included wood felling and cutting, bone work, planning activities, shattering, as well as cutting and carving soft material. She is the first researcher who, from a lithic analysis, manages to determine that the societies ascribed to the Sabana Grande complex are possibly semi-sedentary farmers, due to the identification of mixed activities identified in the lithic analysis. Although this research focused on lithics was pioneering not only in Nicaragua, but also in much of Central and northern South America, it did not have great repercussion and the archaeology of Greater Nicoya and Pacific Nicaragua continued to focus on monumentality and ceramic technologies (for a more detailed discussion see Arteaga, 2017).

It was not until the beginning of the 21st century, when the archaeology of the region was revitalized, and different investigations began to be carried out within the framework of archaeological research projects. Alexander Geurds AND Laura Van Broekhoven initiated a new project which took place in the Chontales region in 2002(Donner et al., 2015). This project focused on recording, identifying and establishing chronologies from surface collections along the Mayales River (Donner et al., 2015). This project had a great continuity with the execution of several field works that sought to map the region archaeologically. In the following years this initiative was renamed PROYECTO ARQUEOLÓGICO CENTRO DE NICARAGUA (PACEN), under the direction of Geurds (Torreggiani et al., n.d.). Within the framework of PACEN, several investigations have been promoted, including studies on statuettes, excavations in particular archaeological sites, petrography records, among others (see Torreggiani et al., n.d.).

Figure 2 Chontales region – Nicaragua. From Wikipedia.

Apart from the initial work on the study of lithic artifacts from Sabana Grande (Gerstle, 1976), van Dalen (2018) conducted a work focused on exploring whether the use of LITHIC MULCH AGRICULTURE (LMA), was a constant in the Chontales region. His findings suggest a use and management of the soil by pre-Hispanic communities. He proposes a direct relationship between the anthropic presence of stones (they can be transported boulders or carving debris), and the presence of fertile soils. This management has been explained by other authors in different parts of the world (Lightfoot, 1994, 1996). The LMA have been defined as the covering with different petrous elements (natural: pebbles, cobbles, tabular fragments or anthropic: knapping lithic products) fields and gardens with stones, pebbles, and similar lithic materials is a variant agricultural strategy that has been used to evade drought and increase crop yield (Lightfoot, 1994, 1996).

On the other hand, Castillo (2018) conducts research where he reanalyzes a sample of the lithic collection of the exploratory pits of the Sabana Grande archaeological site. In this research Castillo manages to determine the lithic reduction sequence of the bifacial tools recovered in that excavation, as well as the identification of other lithic reduction sequences. This research is very important because it is the work that takes up the study of lithics in a region where the complexity of the same stands out, but little has been worked.

2.3 Roberto Amador

Situated on the inside bend of a Mayales River meander, the Roberto Amador site is located over a main alluvial terrace with a higher approx. 30 above the mean sea level and with different levels of terraces on it sides. The site was identified in 2015 by PACEN (Proyecto Arqueológico Centro de Nicaragua) and excavated in the 2018 during the fieldwork by the PRISMA team (Interdisciplinary Archaeological Project Santa Matilde). During the fieldwork, a total of 3[1] pits of 1x1 were excavated along three main levels of the alluvial terrace (lower in the alluvial plain, in the middle step of the alluvial terrace, and in the higher part of the terrace) (Torreggiani, 2020; Torreggiani et al., n.d.).

The pit located at the top of the alluvial terrace was named *Ex. 3* and present, in general terms, a lithic toolkit classified as a reduction sequence for manufacturing bifacial instruments and projectile points. The technological analyses show a homogeneity of shape, size, and manufacturing technique on the lithic artefacts along the different stratigraphic layers. Very few retouched instruments where recovery (without counting the bifacial instruments), and in general terms, the site was identified as a lithic workshop focused on the preparation of bifacial instruments and projectile points. Also, different cultural evidence like human skeletons and pottery suggests that the space where use also as a domestic/burial space. The main layers that make up the pit are the layer 2, which is a layer that according the taphonomic study have been cut by a flood of the Mayales river. The layer 14 is the layer that present the high portion of the archaeological remains, it presents a human tooth in context with the burial of a vessel. The layer 16 is the last layer that presents elements in a relatively high frequency, below this, the layer 18 just present 4 lithic pieces. A very important thing about the excavation no.3, is that it has radiocarbon dates between Cal AD 980-1035 and Cal AD1110-1115 (Donner & Geurds, 2018, 2020; Torreggiani, 2020; Torreggiani et al., n.d.)

In the other hand, the second excavation pit was named *Ex. 2*, and it´s located in the middle of the slope of the alluvial terrace, 30 meters to the west of the top of the terrace. Compared to Ex.3, it presented a lower frequency of lithic material. Despite, the lithic assemblage of this site also shows the remains of a reduction sequence focused on the manufacturing of bifacial instruments and a blade reduction sequence. It is important to mention that this sequence of blades is made on local flint (hydrothermal origin[2] -same for *Ex.3*-) and on obsidian. The main layers that make up the 2 excavations are the 2, which is a layer that present the same composition of the layer 12, it has been cut by a flood. Nevertheless, like the 12 layers, presents an important frequency on the archaeological remains. The other important layer of the 2 excavation is the number 15 which are separated by 3 layers that present a very low frequency of archaeological material. This layer is

[1] The first pit was not considered for the study because presented a very low frequency of lithic material.
[2] Clarification that all the lithic reduction sequence for the bifaces (*Ex. 2* and *Ex. 3*) is made over local flint which have its origins on a regional hydrothermal water.

particularly important because is the one that present lithic evidence of a laminar debitage on the site (Torreggiani, 2020; Torreggiani et al., n.d.).

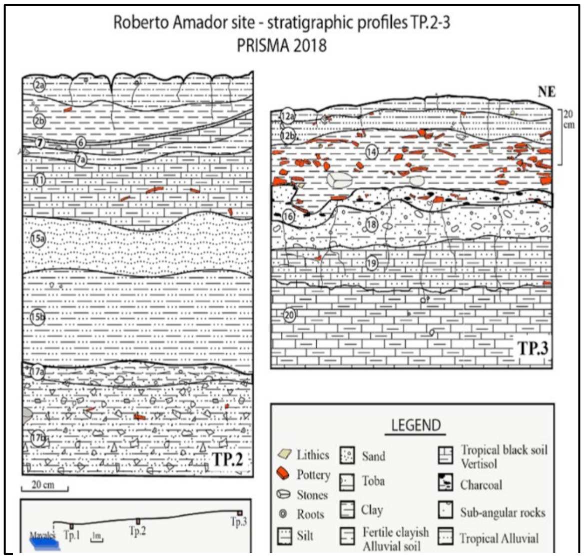


Figure 3 Stratigraphy of the ex. 2 and ex. 3

The preliminary reports of the analysis of different remains (archaeobotany, pottery and human skeleton analysis) suggest that the main terrace was used like a domestic and burial area. Although the lithic evidence collected so far does not disprove these hypotheses, it does suggest a different use of space. Due to the high frequency of *façonnage* flakes, bifacial lithic instruments (different projectile points) which are found fractured during the last moments of manufacture, and a high frequency of cores, the areas of Ex. 2 and Ex. 3 have been interpreted as lithic manufacturing workshops. Particularly ex. 2 suggests a manufacture focused on laminar debitage, while ex. 3 points to a specialization of bifacial type instruments (Torreggiani, 2020; Torreggiani et al., n.d.).

It is worth noting that Roberto Amador stands out for its significant presence of surface materials, as highlighted in the study by Arteaga (2017) and Torreggiani (pers. Communication). These material densities are comparable to those observed at the larger sites of Sabana Grande (Donner & Geurds, 2018, 2020). Several indicators point to the possibility that Finca Santa Matilde (farm were Robeto Amador site is located) served as a source for clay extraction dating back to as early as AD 400 (Casale et al., 2020). Additionally, it is suggested that the site had later functions as an agricultural settlement, as discussed by Donner (2020) and Van Dalen (2018).

3 Methodological approaches to the study of lithic assemblages:

3.1 Technological studies

The study of stone tools and their technological production is a fundamental aspect of archaeological research (Renfrew & Bahn, 2011). Understanding the techniques and processes involved in the creation of stone tools provides valuable insights into the technological capabilities, cultural behaviors, and social organization of past societies. Throughout the refinement of the study of these materials, different techniques of analysis, concepts for interpretation, and discussions have been developed that have not been without heated debate.

Following to the reasoning proposed by Andrefsky (2008), the stone tools are produced by the extraction (and in some cases by the shaping) of a larger piece (core), so it is easy to interpret the life of a stone tool as the linear and unidirectional sequence of the reduction of a stone/core. This has allowed the study of stone tools to be understood as a succession of phases, which are not necessarily continuous or omnipresent, capable of producing the stone tools and found by archaeologists or other. This way of understanding the *stone tool life history* has been interpreted under concepts such as *chaîne opératoire* (Inizan et al., 1999; Lemonnier, 1992; Leroi-Gourhan, 1993) and reduction sequence (Andrefsky Jr, 2008). The use and scope of each of these concepts has been debated by several authors, who have argued for a greater scope of one or the other (M. J. Shott, 2003). For the present research, both concepts are comparable due to the descriptive nature they present with respect to each of the phases present in the creation, use and discard of stone tools.

On the other hand, this research seeks to understand lithic artifacts as an adaptive product of a *technological organization* strategy (sensu Nelson, 1991) developed by a particular community. In other words, it seeks to understand (as far as the data and the limitation of the research itself allow) the selection and integration of strategies for making, using, transporting, and discarding the utensils and materials necessary for their manufacture and maintenance (Andrefsky Jr, 2008; Inizan et al., 1999; Nelson, 1991). According to this line, it is proposed that the classification of the pieces should be as objective as possible, using technological characteristics as classifying features and using to a lesser extent classifying typologies. For this purpose, the classification and terminological description manuals of Inizan et al. (1999), Andrefsky (2008) and Arzarello et al. (2011) will be used.

In order to specify the methodological context of this research, which works with two different types of lithic reduction sequences, it is consider necessary to take up again the theoretical difference between method and technique. According to Inizan and collaborators (1999), technology is conceived as a conceptual approach to material culture, based on the study of techniques and the understanding of gestures, encompassing the entire technical system used in a culture. Thus, technology (whether lithic, ceramic, bone, etc.) not only includes the study of the transformation of a given raw material to make an artifact, but also encompasses all the ideas and decisions that influence the manufacturing process (Inizan et al., 1999; Nelson, 1991).

Although there is an extensive bibliography on the principles of knapping, this research will take the postulates and definitions given by the following authors (Arzarello et al., 2011; Inizan et al., 1999), who start by making a distinction between the concepts of technique and method:

- Technique is defined as the modality of execution. In the case of lithic carving, technique is the physical action that detaches a product (flake) from a nodule (core). In other words, the technique is all the determinations and physical actions necessary for the extraction of a flake (e.g., direct percussion, indirect percussion, etc.).
- Method is defined as the organization of the techniques used for the carving of a given lithic product (Levallois method, laminar method, etc.).

Below, the methods identified in the lithic production of the Roberto Amador site will be defined:

The shaping method is defined by Inizan as "a sequence of knapping operations carried out for the purpose of manufacturing a *single* artifact by sculpting the raw material in accordance with the desired form" (Inizan et al., 1999, p. 43). This method of carving seeks to create a particular morphology which will be shaped by fine retouching or polishing, depending on the objective pursued.

The bifacial shaping type has been used all over the globe and the basic manufacturing concept is the same, differing only in the particular operating schemes of each culture. Two fundamental steps are necessary for the production of a bifacial:

- *Bifacial equilibrium plane*: it consists in the simultaneous fashioning of two mor or less convex surfaces on either side of the piece (Inizan et al., 1999, p. 44).
- *Bilateral equilibrium plane*: it consists in giving the contour a regular shape (Inizan et al., 1999, p. 44).

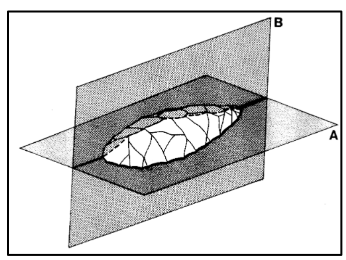


Figure 4 Bifacial (A) and bilateral (B) equilibrium planes of a bifacial (Inizan et al., 1999, p. 45).

3.1.1 Preforms:

It was defined by Inizan as the "result of the particularly careful preparation of a roughout, preliminary to the finishing phase during which one or more techniques are brought into play" (Inizan et al., 1999, p. 51). The final modification of such pieces can be carried out following different techniques, such as percussion, pressure, polishing by abrasion or pecking. For the particular case of Roberto Amador, it has been determined that the final modification of the preforms was carried out by means of percussion and pressure.

3.1.2 Blade/laminar debitage:

It was defined by Inizan as the "result of the particularly careful preparation of a roughout, preliminary to the finishing phase during which one or more techniques are brought into play". the final modification of such pieces can be carried out following different techniques, such as percussion, pressure, polishing by abrasion or pecking. For the particular case of Roberto Amador, it has been determined that the final modification of the preforms was carried out by means of percussion and pressure. The laminar debitage is a type of lithic exploitation that appeared in the Upper Paleolithic, and whose main characteristic is the maximum use of the volume of the raw material (Arzarello et al., 2011). For them it is a debitage that must be planned before the stone carving, organizing the extractions (blades) so that they are as uniform as possible.

3.2 Traceological studies

3.2.1 The study of use-wear traces in the lithic tools. A brief history of the use-wear studies

In the middle of the 20th century, the work of Semenov (1964) became the first English publication on Europe to describe a systematic investigation the use of optical magnification to understand the use-wear of lithic tools.

Initially, this work was published in 1957 in Russian, for which reason it did not have an impact on the Western European archaeological community until years later. The truth is that this publication was the consolidation of a series of experimental, ethnographic and technological works focused on the understanding of the traces of the use of stone tools that began in the mid-1930s (Longo & Skakun, 2005). The English translation of the book "*Prehistoric Technologies*" turned the attention of the Western scientific community (mainly North America and Europe) to this new approach and caused an exponential increase of the works focused on the study of the use traces in the lithic industry (González & Ibáñez, 1994; Keeley, 1980; Odell & Odell, 1980; Tringham et al., 1974; Vaughan, 1985, among others). Although Sergei Aristarkhovich Semenov's work opened the doors to a new world for prehistoric archaeology, allowing the development of a new method that would become a discipline in itself, it was not exempt from misinterpretations by researchers who sought to replicate this type of analysis, as well as discussions and stumbling blocks during its development (Claud & Plisson, 2006; Clemente Conte, 2004; Longo et al., 2005; Mansur-Franchomme, 1986; Marchena, 2021; Vila-Mitjà & Clemente Conte, 2000).

The socio-political context in which Semenov developed his research theoretically marked all the scientistic currents of the Soviet Union, proposing Marxist historical materialism as the main focus of interpretation (Claud & Plisson, 2006). The aim of the functional analysis proposed by Semenov was the reconstruction of the forms or techniques of work. In this sense, his aim was none other than to look for the differences between marks left by different kinematics of use of stone objects. In this task, Semenov was the first researcher to compare the active edges of an experimental collection with the ones of an archaeological collection in order to identify a series of modifications that occurred on the edge. These modifications could be observed with the appropriate optical equipment: with low magnification microscopes (edge damage) at the beginning, and with high magnification microscopes (striae and micro-polishing) years after the consolidation of the traceology methodology.

Despite this, the Western European typological school, led by François Bordes, saw the presentation of Semenov's data and methodology as a certain attack on their typological preconceptions. Some of Semenov data, and the lack of replicability of certain of his experiments, were criticized

(Marchena, 2021). Nevertheless, Bordes did not discard the functional analyses to integrate them within his typologies (Bordes, 1967). A proposal that was not accepted by the Soviet because for him, as for different authors who later developed traceological programs, the typological lists were quite limited at the moment of yielding data for the interpretation of the use of the artifacts (Mansur-Franchomme, 1986, 1999; Pal, 2012; Semenov, 1970). In this regard, it can be said that the morphology of an instrument, in addition to functional aspects, depends largely on technological (availability and type of raw materials, carving methods and techniques, etc.) and cultural criteria (Mansur-Franchomme, 1986). However, it is worth noting the importance of using typologies in the study of the lithic industry, as well as functional analyses.

On the other hand, in North America of the 70's - 80's, different researchers continued the lines of work developed by Semenov. Thus, in some cases the studies focused just on the analysis of the modifications produced in the morphology of the edges of the instruments (e.g., edge damage and rounding) using low magnification equipment (binocular magnifying glass), despite the effort of Semenov for characterized other features in the edge modification by use like polish or striae (González & Ibáñez, 1994; Mansur-Franchomme, 1999). This approach was called the "low-power approach" (see Odell & Odell, 1980; Tringham et al., 1974).

In contrast, another perspective called "high-power approach" was based on the study of the modifications produced in the microtopography of the instruments (micro-polishing and grooves/striae) from the use of high magnification equipment such as metallographic microscopes. This approach was more related to the initial propose of Semenov (see Keeley, 1980; Vaughan, 1985, among others). At the beginning these approaches arose as opposites and became in object of discussion for the research trying to define the best method to see the traces (Berruti & Daffara, 2014; Grace, 1996). In the present, they are currently used together to carry out the study of the use-wear traces because the data and information provided by each of them are complementary (González & Ibáñez, 1994; Marchena, 2021).

Keeley's (1980) work improve the functional analysis methodology. This author pointed out, through controlled experiments and observations made through a reflection microscope, that micro-polishing is specific to the type of material worked. Therefore, he distinguished the micro-polishing resulting from the work of wood, non-woody vegetables, bone, horn, fresh and dry skin or leather, meat, stone, etc. (Keeley, 1980; Keeley & Newcomer, 1977). This research was following by several big investigations that state the principal basis of the use-wear analysis (González & Ibáñez, 1994; Gutiérrez, 1990; Keeley, 1980; Vaughan, 1981).

To conclude, despite the important advances in the microscopic-based functional analysis methodology, functional studies present some limitations that must be taken in consideration (González & Ibáñez, 1994). First, taphonomic alterations resulting from post-depositional processes can eliminate or mimic traces of use (Berruti & Daffara, 2014; Grace, 2012; Keeley, 1980; Kononenko, 2011; Vaughan, 1981). Second, traces of use depend on a wide range of interrelated factors such as the time of use, the type of materials worked, and the mode of use of the tool (Keeley 1980; Pal 2012; Lerma, 2008, among others). Al these factors have to be part of a use-wear investigation in order to obtain the most accurate data for interpret the use of the lithic toolkit.

3.2.1.1 Independent and dependent variables.

The traceological study intrinsically requires an experimental program that allows scientifically contrasting the hypotheses raised in archaeological research (Eren et al., 2016; Marreiros et al., 2020; Odell & Odell, 1980). Throughout the experimental program, the behavior of stone artifacts during their use on different materials must be studied and recorded. This activity should generate not only empirical knowledge about the performance of these artifacts, but also generate a frame of reference data about the traces of use-wear on the worked edges of the stone tools. It is necessary to control the variables that intervene during the experiment. In this regard, the type of variables that are involve during the realization of a program of experimentation of traces of use have been defined:

3.2.1.1.1 Independent variables:

"*(…) are those to be manipulated in order to measure their effects on the final result.*" (Marreiros et al., 2020, p. 13)

These variables are those factors that interact with each other during the use of the instrument and that significantly influence the traces resulting from the work. Also are the ones over which the operator has total control. Authors like González e Ibáñez (1994) and Gutierrez (1990) divided these variables in two groups: the "primaries" are the basic objective in the functional interpretation, and we only have evidence of them through the traces (they are the activity, material worked, time of use and way of holding the tool) (Gutierrez, 1990). The "secondary" group includes the variables that significantly influence the traces of use (angle and delineation of the edge, nature of the active zone and type lithic raw material) and are evident from the tool observation (González & Ibáñez, 1994; Lerma, 2008).

The way in which each of these variables intervenes during the work, determines the type of resulting traces of use (Lin et al., 2018). For example, it's possible that a hard material like dry bones, will create a bigger and deep edge damage in the lithic artefacts than a soft material like meet (Vaughan, 1981); also, it's possible to identify the type of movement and action applicated in the instrument by observing the type, distribution, and localization of the edge damage on a lithic tool (Gijn, 1989, among others).

Regarding the work gesture, it can be mentioned that depending on the action performed, particular traces of use can be generated (the gesture is linked to the activity developed with the instrument and how it transforms the worked material, in other words: the work kinematics)(Lerma, 2008).

THE ACTIVITY

The activity is the way in which a lithic tool transforms the material worked and contemplates the type of relationship that is established between the tool and the material worked (González & Ibáñez, 1994). It is defined by Gutierrez (1990) like the "*set of **actions** that make up a broader production and have more complex purpose*"[3]. In this sense action is defined as "*the set of **mechanical gestures** that are executed in a specific task*"[4]. The activity is a complex variable because

[3-2] translation and bold type made by the author.

it can contain several sub-variables which will have different categories to take in consideration: morphology of the active edge, the kinematic work, the position of the edge regarding to the movement (gesture) and the angle of the work (González & Ibáñez, 1994; Gutiérrez, 1990; Lerma, 2008; Odell & Odell, 1980).

The identification of the activity with the material worked is one of the main purposes of the use-wear analysis.

The action of the work will be guided by a several Sub-variables that have been taken in consideration. According to Gutierrez (1990) and González e Ibáñez (1994), the sub-variables more important are the morphology of the active edge (pointed, lineal, bevel burin, massive), the worked angle (there are two categories: oblique angle -near 45°- and straight angle -near 90°-), the application of the force (percussion -direct percussion and indirect percussion- or pressure). In general terms, the morphology of the active edge will condition the type of work that the instrument can done, and the kinetic of the work will conditionate the characteristics of the traces (Lerma, 2008; Pal, 2012).

Most of the identifiable actions in the use-wear traces are made over lithic tools that use pression as technique for application of the force. In this sense several researchers, (González & Ibáñez, 1994; Keeley, 1980; Lerma, 2008; Odell & Odell, 1980; Tringham et al., 1974; Van Gijn, 1989; Vaughan, 1981), have determined that the type of movement can create identifiable traces.

There are different types of gestures involving on the creations of traces:

a) **Longitudinal gesture**: in this gesture there are recognizable two different actions, cutting (associated with a unidirectional movement) and sawing (associated with a bidirectional movement). It has been determined that the application of either of the two will depend on the material to be worked on. While it has been determined that the cutting action is more effective for soft materials (centripetal movement -towards the operator- and centrifugal movement -from the operator-), sawing is more effective for hard materials (Bianchi, 2010; Tringham et al., 1974).
b) **Transverse gesture**: are those oblique, linear and transverse actions where the edge of the tool is perpendicular to the direction of movement (Keeley, 1980). In this regard, Gassin (1996)(Bianchi, 2010) has distinguished two types of transversal actions. The first is the positive cut, where the angle of action is greater than 90 degrees; and second, the negative cut, where the actuation angle is equal to or less than 90 degrees. This gesture is related to actions such as scraping, brushing, and smoothing that can be performed unidirectionally and bidirectionally (González & Ibáñez, 1994; Gutiérrez, 1990; Keeley, 1980; Lerma, 2008; Tringham et al., 1974).
c) **Punctual gesture**: it can be a transversal or longitudinal movement using a point created by two actives edges (Gutiérrez, 1990)**.**
d) **Rotary gesture**: they are rotary or semi-rotational actions performed on a support, usually pointed or triangular (Keeley, 1980). This gesture is linked to actions such as drilling and trepanation (González & Ibáñez, 1994; Gutiérrez, 1990; Keeley, 1980; Lerma, 2008; Tringham et al., 1974).

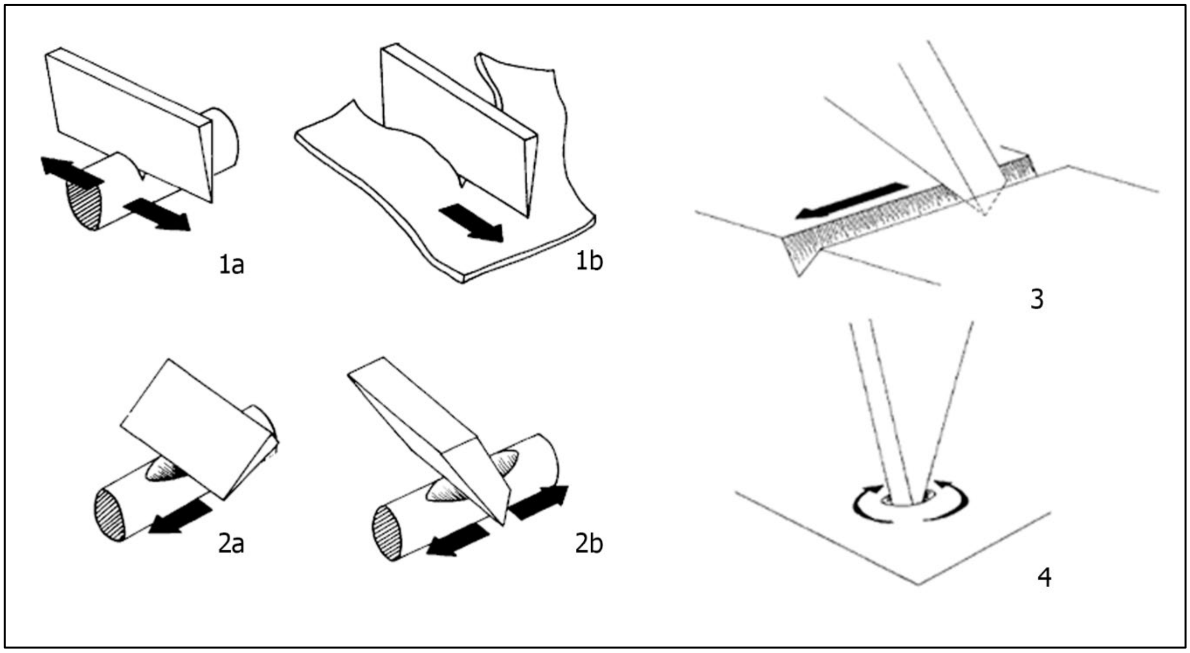


Figure 5 Longitudinal gesture (1a -unidirectional- and 2a -bidirectional-). Transversal gesture (2a -reduce or brush- 2b -smooth or scrape-). Punctual gesture (3). Rotatory gesture (4). Modified from González and Ibañez, 1994.

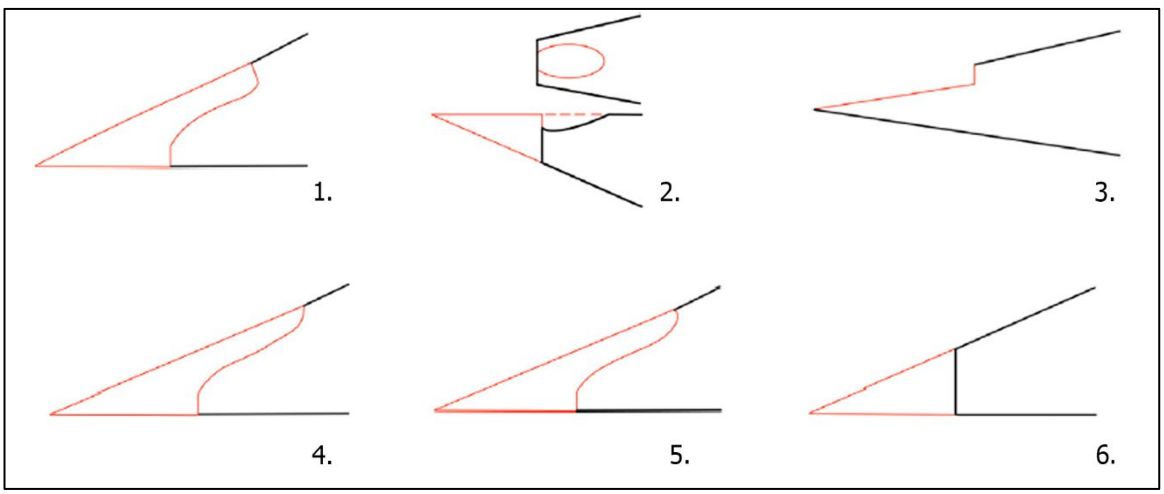


Figure 6. Main impact fracture types. 1. Step terminating bending fractures (a bending fracture terminating in a 90°). 2. Unifacial/Bifacial spin-off fractures>6 mm (a secondary fracture type originating from bending fractures such as step terminating on a snap fracture). 3. Impact burination (a bending fracture resembling a burin spall terminating in either a 90° step, feather or hinge on the lateral side(s) of a tool). 4. Feather terminating bending fracture (A bending fracture terminating in an acute angle or in a curve less than 90°). 5. Hinge termination bending fracture (a bending fracture terminating in an upturned curve or lip). 6. Snap fracture (a bending fracture in which the bending forces act to snap the tool in a clean break). From Pargeter (2013).

The other common technique in the application of the force is the gestures creates by percussion or thrown percussion. The first one can create actions like axes work, hoe, chop or puncture, and the second one is regarding to throwing actions like spears, arrows or any other projectile point (González & Ibáñez, 1994; Gutiérrez, 1990). Several authors have work on the experimentation about the diagnostic impact fractures that can development in a longitudinal impact presenting some characteristics (Asryan et al., 2014; McBrearty et al., 1998; Pargeter, 2011, 2013; Shea & Klenck, 1993). The results show that the macro-fractures are similar to the taphonomic marks led by trampling by cattle and particularly Pargeter (2011) explain that for understand this type of fracture of "thrown percussion" is more useful do a macro-traces approach than a micro-trace. Also, the author points that the location, co-occurrence, type, and proximity to retouch on a tool have important means of distinguishing between weapon and non-weapon tool. Also, his result allows to say that the rock type variation plays a less important role in in the impact fracture formation Pargeter (2013). The fractures presented in point of the thrown weapon of the Pargeter experiment can be summarized on the Figure 6.

The most characteristics fractures for identify a tool as a thrown instrument are step terminating, impact burination bending fracture and bifacial spin-of fractures. In contrast, the spin-off fractures less than 6mm were commonly associated with trampling taphonomic process (Pargeter, 2013).

THE WORKED MATERIAL

These are all possible materials that can be worked with the lithic instrument in prehistoric times. The most common worked material tested during the experiments is leather, bone, antler, wood, shell, and plants. It´s common that this material doesn't last over time and its presence has to be inferred by direct (e.g., residues analysis, etc.) or indirect presence (e.g., use-wear analysis).

The characteristics of the material with which the tool comes into contact considerably influence by the type of marks that are generated during work. This has led to the control of this variable being one of the most attended in most of the experimental programs (Clemente Conte et al., 2015; González & Ibáñez, 1994).

The quality of the worked material that is most related to traces of use is hardness, although the influence of factors such as ductility, flexibility, deformability, viscosity or elasticity has also been pointed out (Gutierrez, 1990). Other authors have defined the hardness with several categories creating a big mosaic of hardness in worked material (Keeley, 1980; Odell, 1981; Odell & Odell, 1980). For the present research we defined the hardness category taking in consideration the postulates of Odell-Odell (1980):

Hardness	Worked Material
Soft	Animal products such as meat, skin, and fat. Vegetal substances such as tubers, rhizomes, stalks and leaves. Scarring
Soft medium	Soft woods (coniferous trees). Fresh stalks, dry meat, grass
Hard medium	Soaked hard woods. Soaked antler and fresh bone.
Hard	Dry bone, antler and hard wood

Table 1 Classification of the hardness of the worked material Adopted and modify form (Odell & Odell, 1980).

WORKING TIME

As we will see later, the time of use is a fundamental factor in the development and characteristics of the fingerprints. Gutierrez (1990) considers that it is, together with the material worked, the main variable that influences the formation of the polish.

González and Ibañez (1994) and other authors (Lerma, 2008) have been emphatic in mentioning that there is no distinction between measuring this aspect (instrument work) by time of working or number of strokes/movements. However, they mentioned that is necessary used the lithic instrument until macro-traces can be identified with the "naked eye".

Therefore, the correct reading of the traces will allow us to identify both the material and the action carried out on it.

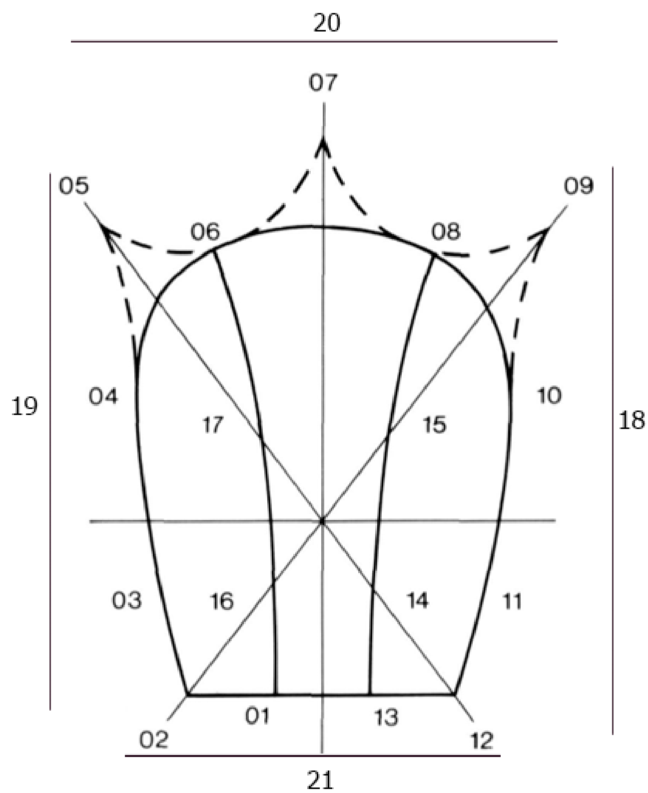


Figure 7 Coordinate system proposed by Van Gijn (1989), and modify by Berruti and Daffara (2014)

RAW MATERIAL

The raw material is one of the most important independent variables that use-wear studies have to deal with. Depending on the type of the archaeological raw material is manufactured, certain types of micro/macro traces will occur with more or less easily. That's why, it's very important to recreate the experiment (knapping and use the lithic artifacts) with the same archaeological raw material. This will allow to create a direct correlation between the data collected through the experiment and the data recorded on the archaeological sample.

COORDINATE SYSTEM

Finally, it's important to mention that for located the macro and micro traces over experimental and archaeological samples, the coordinate system proposed by Van Gijn (1989), and modify by Berruti and Daffara (2014), was used (see Figure 7).

3.2.1.1.2 Dependent variables:

"(…) *are those "dependent" on the independent variable, which are expected to change based on the latter, and are therefore the ones being measured. The independent and dependent variables may be viewed in terms of cause and effect.*" (Marreiros et al., 2020, p. 13)

What is commonly understood as dependent variables are those traces that depend on the independent variables described above. The recognition and the understanding of the organization and morphology of these traces allow the researchers to identify the functionality of the analyzed tools (Berruti & Daffara, 2014; González & Ibáñez, 1994; Leipus, 1981; Mansur-Franchomme, 1986). These variables can be observed in two different approaches, the *low power approach/macro-traces* (**edge removal/microchipping** -in some cases it´s possible observe striation microscopely-) and the *high power approach/micro-traces* (it´s possible to observe **polish**; **striation** and **edge rounding** -also you can observe in high microscopy some residues, but in this research, we will not focus on that subject-). There are some traces that can be identified by using electronic microscopes like micro-residues (this research will not explore the presence of this type of residues on the assemblage).

To facilitate their presentation, we have called the first one "Macro-traces" and the last two "Micro-traces".

LOW POWER APPROACH/MACRO TRACES:

As mentioned in one of the previous paragraphs, the study focused exclusively on macroscopic traces and has been involved in discussions and experiments that have demonstrated the low validity to determine the use of the stone artifacts. It is for this reason that for several decades the analysis of these traces has been carried out at the same time as the analysis of microscopic traces (see previous paragraphs). However, it is important to emphasize that the study of these traces has the advantage of identifying mainly the gesture of use and the preliminary identification of the hardness of the worked materials.

The main macroscopic trace that can be identified is *edge damage*, which is visible to the naked eye, but can be correctly characterized at low magnification:

<u>Edge damage</u>

Edge damage are small negative flakes that are generated on the active edge of the tool by the force exerted by the operator against the worked material. Basically, it is the physical-mechanical properties of the worked stone, especially the conchoidal fracture, which allow the creation of these traces on the edge. The production and morphology of these traces will depend on different factors, among the hardness of the worked material, the force developed by the operator, the position and type of movement of the active edge with respect to the worked material and the resistance of the raw material with which the lithic instrument is manufactured. Given the morphological characteristics of this use trace, it is possible to study it by means of "low-power" binoculars (González & Ibáñez, 1994; Mansur-Franchomme, 1986; Odell, 1981; Odell & Odell, 1980; Tringham et al., 1974).

At the end of the last century there was a discussion about the validity of flaking in the functional interpretation of lithic tools. Different researchers from Harvard, led by Ruth Tringham and George Odell, supported the existence of a direct relationship between the type of edge removal (size, morphology, distribution, etc.) and the type of task/action/material worked. In other words, it was proposed that the study of the different types of edge damage serves to make a functional diagnosis of a lithic instrument in order to determine the task performed, the type of gesture involved, and the material worked (Odell, 1981; Odell & Odell, 1980). However, another group of researchers questioned this assertion explaining that due to the generalized forms in the edge damage it is difficult to determine the use of the instrument (Keeley, 1980), added that several taphonomic processes can generate similar edge damage to those produced by use such as trampling (González & Ibáñez, 1994; Grace, 1990; Keeley, 1980; McBrearty et al., 1998; Shea & Klenck, 1993).

The present research will take the postulates described by Tringham (1974) and González Ibanez (1994) for the characterization of edge removal. This will be done in order to identify main elements such as the type of gesture used in the lithic instrument and the hardness of the worked material.

Characterization of the Edge removals:

- **Number of edge damage/removal**: It has been suggested that the higher the number of spalling is directly related to the hardness of the material worked (González & Ibáñez, 1994; Gutiérrez, 1990; Odell & Odell, 1980; Tringham et al., 1974). In the same sense, different authors have also related the amount of edge damage with the angle of work, associating acute angles with greater amounts of flaking (Keeley, 1980), the time of use (Odell & Odell, 1980; Tringham et al., 1974), the type of gesture, transverse gestures tend to produce a greater amount of edge removal than longitudinal movements (Gutierrez, 1990), and the type of silex used (hardness of the raw material) (Clemente Conte et al., 2015).

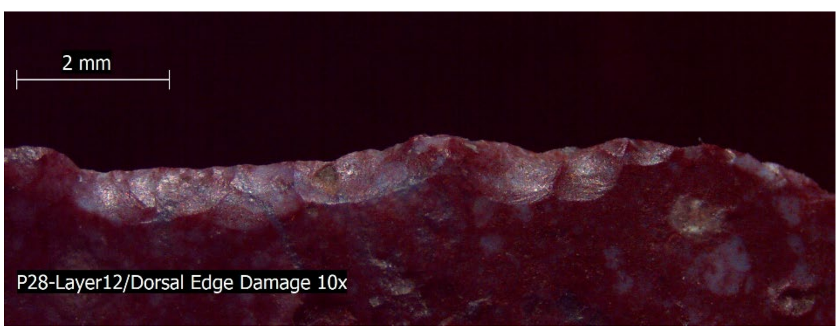


Photo 1 Edge removals recorded on an archaeological flake.

- **Position of the edge damage/removal**: The position of the edge removal record if the negatives are positioned unifacial or bifacial and is directly related to the type of gesture used with the instrument (González & Ibáñez, 1994, p. 38). In this regard, Tringham (1974, pp. 188–189) argue that in transverse movements the edge removal appears on the conducting face. However, authors such as Keeley (1980) have recorded that spalling also occurs (less frequently and to a lesser extent) on the contact face of the instrument. Following the postulates of Odell-Odell (1980), González and Ibáñez (1994) and Keeley (1980), this research will take as reference the presence of edge damage in a unifacial position as a product of a transversal gesture. While edge removal in a bifacial position will need to a further observation to understand the type of gesture. As mentioned by Gutierrez (1990), we consider that the attribute of the position of the edge damage will allow us to distinguish the kinematics of the tool, the working angle and mainly the hardness of the material worked.

- **Arrangement**: the order of placement of the edge damage in relation to the others will be recorded. According to González and Ibáñez (1994) they can be isolated, aligned or superimposed (see Figure 8).
- **Distribution**: the distribution of edge removal along the active edge will be recorded (continuity or discontinuity). In this regard, González and Ibáñez (1994) and Tringham et al. (1974), recorded that a regular distribution of flaking on the active edges can be associated with two causes: transverse gestures (produce a continuous distribution in contrast to the longitudinal gestures that tend to present a discontinuous distribution) and hardness of the worked material (as the hardness increases, the distribution will be more continuous).

Figure 8 Distribution of the edge damage. Isolated, aligned and overlap. From González e Ibañez, 1994 p. 39.

- **Morphology**: the general morphology of the edge damage will be recorded. In this sense, the characterization proposed by Tringham (1974), adopted and modified by González and Ibáñez (1994) and Gutierrez (1990) will be used for the present research. In this classification 6 different types of morphologies are proposed (see Figure 9). However, it is important to mention that Keeley defined 7 types of edge damage that would be differentiated according to their morphological characteristics (see Table 1). However, Odell-Odell (1980) managed to relate the type of edge damage to the hardness of the material worked, defining 4 types of hardness (Soft, medium soft, medium hard and Hard) or resistance to pressure that could generate different types of edge damage that most of the time can be recognized (see pages above).

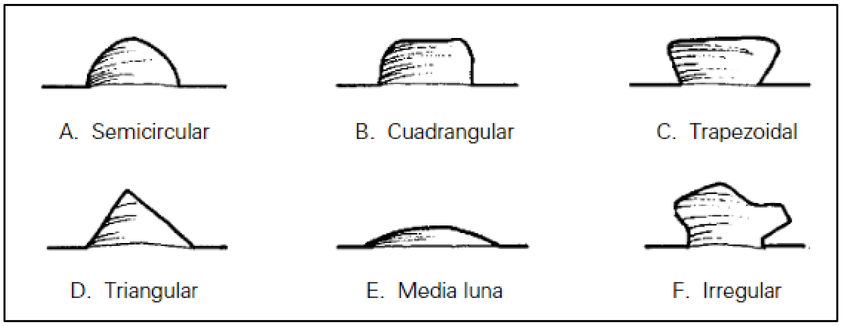


Figure 9 morphology of the edge damage. A. Semicircular; B. Quadrangular; C. Trapezoidal; D. Triangular; E. Half-Moon; F. Irregular. From González e Ibáñez, 1994, p 40.

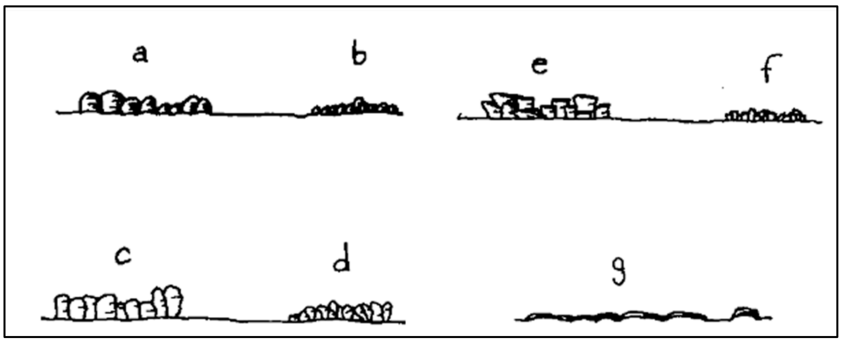


Figure 10. Edge damage types. (A) large Deep scalar, LD; (B) small deep scaler, SB; (C) large shallow scalar, LS; (D) small shallow scalar, SS; (E) large stepped, L Step; (F) small stepped, S Step; (G) Half-moon breakages. From Kelley, 1980 p 24.

Although different authors relate and characterize other physical features of edge removal for a detailed record of the appearance it, in the present research only the characteristics described above will be considered for the analysis. However, other physical characteristics for the morphological recording of the edge removal will be described below:

- **Termination of the edge removal**: this aspect seeks to characterize the distal zone of the edge removal. This characteristic is related to the activity carried out by the instrument, as well as the hardness of the material worked. Odell and Odell (1980), relate the reflected and stepped terminations to the percussion actions. Therefore, it is proposed that the smooth terminations will be the product of working with soft materials, while the reflected/hinge and stepped terminations are characteristic of working with hard materials (Keeley, 1980; Odell & Odell, 1980; Tringham et al., 1974).
- **Length and width**: the length of an edge removal is considered as the distance between the two sides of it, while the width will be the distance between the distal and proximal zone of the negative. This morphological characteristic has been interpreted as an indicator of hardness in the worked material (Odell, 1981). On the other hand, and as mentioned by Gutierrez (1990) and Keeley (1980), activities of greater violence such as percussion over pressure will tend to generate larger flakes.

HIGH POWER APPROACH/MICRO TRACES:

These types of traces are defined as modifications of the crystalline structure of the rock that produce changes in the surface and alter its microtopography (Keeley 1980). Three types of micro-traces are recognized: micro-polishing, rounding (on edges and/or ridges) and striations. These types of micro traces should be considered together within the analysis. The identification of these types of traces requires the use of metallographic microscopes and/or scanning electron microscopes (SEM).

Micro-polish

Although the study of polishes is currently one of the spearheads of traceological analysis, their definition and characterization throughout history has not been exempt from speculation and debate. It was not until Keeley's pioneering work in the 1980's that the idea of polish types could be associated with the use of the instrument on different materials.

These traces were defined by Keeley (1980) as those aspects of the surfaces of the active edge that reflect the incident light differently from the unused areas (Pal, 2012). From certain characteristics of the micro-polishing, such as brightness intensity, thickness, distribution and surface appearance, it is possible to determine the type of material worked (soft, medium, hard) (Keeley, 1980). However, it is important to mention that this micro-trace can be the product of different processes unrelated to the use, such as technological processes typical of stone carving, taphonomic processes such as trampling, among others (Grace, 1990; Keeley, 1980; McBrearty et al., 1998; Shea & Klenck, 1993).

The formation of micro-polish has been explained by different authors (Mansur-Franchomme, 1999), being the explanation given by Andreson Gerfaud (1980) the most accepted in the scientific community (Pal, 2012). He states that the micro-polishes are formed by a process that includes the dissolution of a part of the superficial silica in the zones of the active edge, and which are melted by friction to later solidify as a mass of amorphous silica, which in some cases can incorporate fragments of the worked material (Mansur-Franchomme, 1986; Pal, 2012).

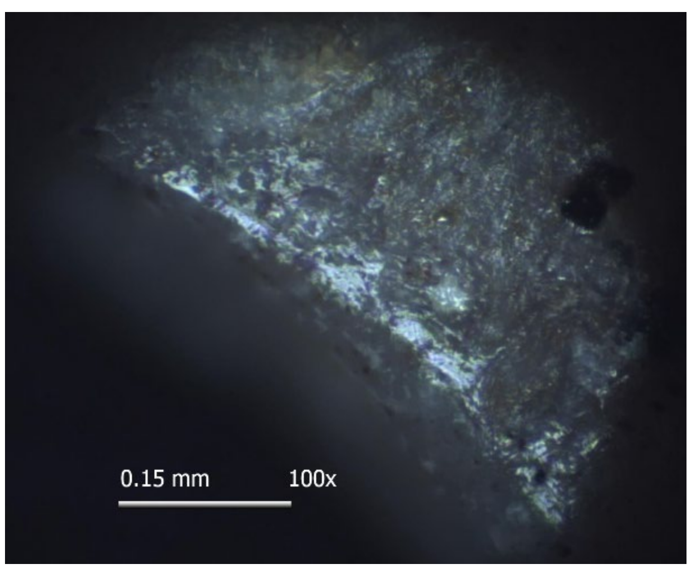


Photo 2 Sample 30-experimental collection. Coordinate 08, ventral face 100x. Polish in the active edge.

There are several proposals for the classification of micro-polishes, and these tend to diversify when researchers raise particular problems such as the exclusive use of a raw material other than flint (Clemente Conte et al., 2015; Kononenko, 2011; Vaughan, 1981), or when the research is focused exclusively on a particular worked material (e.g., processing of plants) (D 'Errico, 2014; Fullagar, 1991).

For the present research, the physical and morphological characteristics described by González Ibanez (1994) will be taken into consideration, which in turn were adopted and modified from the initial proposal of Keeley (1980):

- **Mesh/Weft**: the aim is to record the degree of chaining between different polished zones. This concept is related to the one described by Grace (1985) as *development*, or Vaughan's (1985) *degree of chaining*. This has been defined in 4 different degrees:
    - **Compact**: when the entire weft is polished.
    - **Closed**: the polished zones are interlocked and theoretically occupy more than 50% of the polished surface.
    - **Semi-closed**: the polished zones begin to link together and occupy less than 50% of the polished surface.
    - **Open**: when there are isolated polishing points that are not linked to each other.
- **Microtopography**: seeks to record the regularity of polished surfaces. Normally the surface of lithic raw materials tends to be irregular (with the exception of certain obsidians) before being altered by use. As the surface of the active edge comes into friction with the worked material, the microtopography of the surface begins to regularize. Three types of microtopography can be distinguished:
    - **Smooth**: when the surface already polished apneas irregularities.
    - **Wavy**: when the polished surface forms smooth elevations and depressions.
    - **Irregular**: the original surface is scarcely altered, and the appearance of the polished area can be confused with an unused area. For this reason, those pieces that present an irregular microtopography will be catalogued as pieces with a *possible use*, following the proposal of Pal (2012).
- **Position of the edge damage/removal**: The position of the edge removal record if the negatives are positioned unifacial or bifacial and is directly related to the type of gesture used with the instrument.

<u>*Striae*</u>

Striae are marks formed by linear depressions that form on the surface of the instrument and which have defined limits (González & Ibáñez, 1994; Gutiérrez, 1990; Lerma, 2008). It is possible to identify polished striae, which have been recorded by Grace (1985). Their formation is due to the frictional dragging of abrasive material on the surface of the instrument (González & Ibáñez, 1994; Gutiérrez, 1990). The striae allow the reconstruction of the kinematics of the tool by indicating the direction in which it was moved. There are some researchers who have associated types of striae with worked material (Keeley, among others), but these are recognized as trends because there is no consensus among the community (González & Ibáñez, 1994, 2003).

It is important to mention the reflection made by researchers such as Vaughan (1985, p. 12) or Keeley (1980, p. 35), on the tendency for instruments not to develop these marks during use.

Different experiments have shown that the presence of abrasive agents such as sand, soil, or the same humidity of the material being worked, have a direct relationship with the generation of these marks. This adds one more variable to the study of these marks (Bamforth, 2010; Gutiérrez, 1990; Kononenko, 2011; Semenov, 1964; Shea & Klenck, 1993; Van Gijn, 1989, 2014; Vaughan, 1981).

These marks are intimately associated with gesture. These have been defined as grooves, depressions or additions that occur on the surface of the edges due to their use. Some observable characteristics of the grooves with respect to their position on the active edge can indicate the type of gesture used during the work:

- Striations parallel to the active edge suggest **longitudinal actions**.
- Perpendicular grooves to the active edge suggest **transverse actions.**

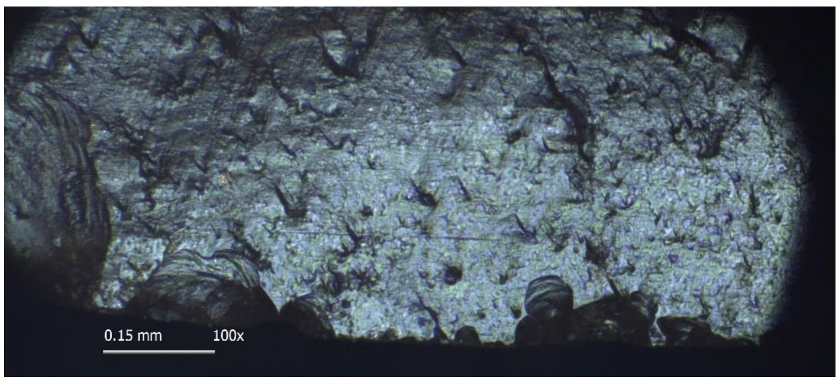


Photo 3 Sample 17-experimental collection. Coordinate 04-03, Dorsal face, 100x. Striae

Also, the position (unifacial or bifacial) of the striae is important for recording the type of gesture during the work.

Abrasion tracks or blunting

Is a variable that does not require high magnification to be recognized since it is the rounding suffered on the edge or the ridges of the lithic surface. The edges and the elevated areas of the micro-topography of the rock are due to the abrasion produced during the action (Grace, 2012; Grace et al., 1985; Keeley, 1980; Vaughan, 1981). This trace must be related to other attributes so that the interpretation of the identification of the worked material is precise (Berruti & Daffara, 2014). Also, it’s important to mention that these marks can be produced by different taphonomic processes related to transport or post-depositional processes (Keeley, 1980; McBrearty et al., 1998; Shea & Klenck, 1993; Van Gijn, 1989; Vaughan, 1981).

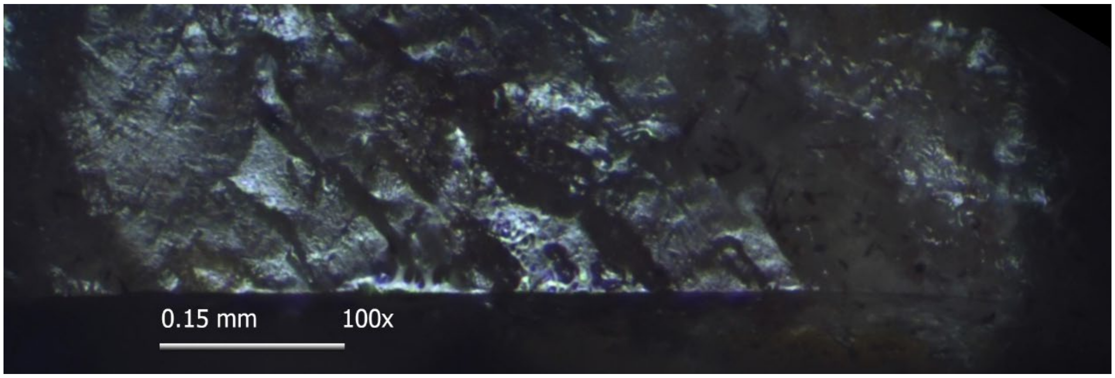


Photo 4 Sample 18-experimental collection. Coordinate 11, ventral face, 100x. Rounded edge.

To conclude, it is worth emphasizing Bamforth's (2010) statements about the historical error of us archaeologists in trying to interpret the different use wears with the empirical evidence (referring to archaeological objects). In archaeological research, the question of inferences about tool use has been addressed from different approaches. Typically, it is assumed that there is a connection, at least in a general way, between tool forms and tool uses, and this connection is implicit in archaeological typologies. This inference has made that some of the archaeological research that does not develop a program to study the use-wear classify with typologies lithic pieces that do not play the same functions that their typologies suggest.

Even in cases where our hypotheses about the relationship between the form and function of a tool are correct, knowledge of a tool's potential use does not necessarily imply knowledge of its actual use, nor whether it was ever used. For example, deducing the use of a tool from the measurement of the angle of its cutting edge presupposes that it was indeed used for that purpose. Furthermore, none of the approaches used to infer tool uses provide specific information about the tasks they performed. For example, if a specific tool is a scraper, *what was it used to scrape?* Bamforth (2010, p. 95) ask for himself. It’s important that the interpretations regarding the use of the different archaeological tools is always accompanied by empirical/analogical evidence/data. We share the concern of the author when he suggests that it´s important to keep in the cabinet the linking of typologies with uses in tools.

3.3 Experimental studies

3.3.1 Introduction

The importance of experimental programs within archaeological studies has become a basic and necessary tool to obtain a better correlation between the hypotheses raised and the cultural remains studied (Eren et al., 2016; Flores, 2010; Lerma, 2008; Lin, 2014; Marsh & Ferguson, 2010; Outram, 2008; Semenov, 1964; M. J. Shott & Sillitoe, 2005). Also, to understand the historical events its necessary assume that there are certain rules of the present that rule the past (Stout, 2002). To achieve a correlation between the latter, it is necessary to design a structured experimental program that is focused create a correct dialogue between the hypotheses, the variables to be studied and the analogies that they will be made on the archaeological remains (Lerma, 2008; Lin et al., 2018; Outram, 2008).

During the last decades several authors have made a great effort to theorize about how experimental programs should be scientific protocols through standardization, structuring and their replicability capacity (Carr & Bradbury, 2010; Domínguez-Rodrigo, 2008; Gifford-Gonzalez, 1991; Lee Lyman, 2004; Marreiros et al., 2020; Outram, 2008; Wylie, 1988).This has make that experimental analogies in archaeological investigations increase in number and become a crucial key for the understanding of archaeological context in the last decades (Lin et al., 2018; Outram, 2008). In this regard, numerous ways of building experimental protocols have been proposed to understand different aspects of the life forms of past hominin groups (Burton, 1980; Carr & Bradbury, 2010; Flores, 2010; Marreiros et al., 2020; Stone, 2011, among others). In this sense, it is important to understand that experimental protocols are not the final products in themselves, but rather a means to achieve a more accurate interpretation of the hypotheses that archaeology needs (Eren et al., 2016; Outram, 2008). It's just a way to achieve interpretative data. It is necessary to clarify that although an experimental program seeks to obtain data that will be compared with archaeological samples through analogies, these will essentially always be an incomplete comparison (Domínguez-Rodrigo, 2008; Eren et al., 2016). This is because the analogies that the experimental programs will reproduce will only be able to control the variables that are sought to be studied/tested and not the behavioral or ecosystem variables on which the first ones were produced (Lin et al., 2018). In fact, the researchers have defined several types of experiments, being the *actualist* and the *controlled* the most recognized (Gifford-González, 1991; González & Ibáñez, 1994).

The *actualist* approach is an experimental study that involves more qualitative methods, and a lower degree of variables control because it pretends to reproduce the works carried out by the prehistoric man in the most faithful way possible to understand the type of evidence that are produced. This evidence will be used in an analogical-comparative way to interpretated the archaeological remains and traces by the archaeologist. From this perspective, the actualism experiments present just a partial approach to the understanding the phenomena studied in the past through modern analogies and "*requires the imposition of specific assumptions and inferences to give it archaeological meaning.*" (Eren et al., 2016, p. 106) In other words, the problem and limitation of the actualistic experimental programs start from the selection of the tasks that are going to be reproduced, because the replicative system will not recognize other tasks than the proposed in the experiment (Gifford-González, 1991).

In the other hand, the *controlled* experiment is characterized by testing individual variables and the interaction between them, usually by mechanical methods (Eren et al., 2016). In this second, the aim is to keep a strict control on the variables, to understand how they interact with the activities/prehistoric works. The final goal is to stablish a relation between the direct and indirect variables (Gifford-González, 1991; J. Marreiros et al., 2020) (For this research, will be the relation between the work variables vs the use-wear traces.

In this regard, Gifford-Gonzales (1991) raised the difference between the use of "*formal analogies*" and "*relational analogies*" (Domínguez-Rodrigo, 2008; Lin, 2014; Lin et al., 2018). The former analogy is defined as those analogies that are based on the ordinary experience of the observer, formal analogy operates by "*drawing a causal connection between observed modern process and its material outcome.*" (S. Lin et al., 2018; p 665). It means that when an archaeological item shares morphological similarities with a modern object, it is assumed the same modern process works also for creating the objects in the past (see also the concept of *internal and external validity* on the experiments and the archaeological remains which proposes - (Eren et al., 2016). This is a common analogy used by many researchers in the archaeological field, and Gifford-Gonzales (1991) mention three main keys for using this type of analogy:

- There should be formal similarities between the archaeological object and the modern object.
- There should be a linkage on the modern process that creates the object, and it has to be casual.
- The inferred process is uniformitarian and thus can be projected to the past.

In other words, we can say that those archaeological objects to which there is a contemporaneous equal, can share the same processes of production, use and discard. To demonstrate this, is not needed just an experimental program, also technological, use-wear, and ethnographic programs are useful.

In the other hand, relational analogies work by understanding the past object through a corpus of knowledge that its already understand ("systematic and causally based") and can be infer in the past object. (Domínguez-Rodrigo, 2008; Gifford-González, 1991). In fact, the uniformitarianism has been assumed in this type of analogy by a corpus of data that other archaeologist has defined as referential frameworks (*sensu* Binford, 1980). It means that because a particularities characteristics observed on the past object the researchers can identify the creation process.

Regarding the study of use-wear analysis in archaeology, experimentation plays an equally important and necessary role as the analysis of traces in archaeological artifacts (Bamforth, 2010; Keeley, 1980; Semenov, 1964). According to this, and as mentioned by Outram (2008), experimental archeology (and particularly the study of traces in artifacts) must be considered as a scientific methodology by using the same hypothetical-deductive process (sensu, Popper, 2002) to falsify or validate the hypotheses put forward. In this sense, if a hypothesis can be falsified according to the experiment, it will be discarded, and replaced with a new. But if a hypothesis is tested as valid, it does not mean that it's a true. It means that the way this hypothesis has been constructed can be continued used until its falsified and replaced by better set of principles – *equifinality problem*- (Carr & Bradbury, 2010; Lee Lyman, 2004; Marreiros et al., 2020).

The use-wear analysis methodology allows us to address the context of use of the lithic materials studied (Semenov, 1964). In this way, a global vision of the artifactual set can be obtained from inferring the function of the artifacts, the material on which they worked, and the activities carried out in a specific context, that is, the way in which they were used within of a social system (Keeley, 1980; Pal, 2012). The proposed method for understand the use-wear traces on the lithic remains of RA site, is based on three fundamental pillars: 1) the development of an experimental program, 2) the observation and characterization of the traces that develop on the edges of the instruments as a result of their use in the processing of different materials and 3) the analysis of archaeological collections via analogies. The analysis of the use-wear context constitutes one of the main ways to explain the dynamics in the production of artifacts and, and the processes of obtaining, producing, and consuming resources in which the artifacts participate as instruments of work (Pal, 2012).

Due to the nature of the present research, the experiment protocol will take in consideration several variables to test to create a complex referential framework. This will allow relational analogies that guide the understanding of the lithic process. The protocol for this research can be observed on the chapter of Materials and Methods.

4 Materials and methods

The artifactual lithic assemblage analyzed in this research is part of the archaeological record recovered within the framework of the PACEN research project ("Proyecto Arqueológico Centro de Nicaragua") in the excavation that took place in the 2018 field season, at the archaeological site "Roberto Amador" in the region of Chontales, Nicaragua. This assemblage is part of a representative sample of 30% of the lithic sample recovered from the site and selected for study by the University of Ferrara, Italy. This set has a total representation of 2059 lithic pieces distributed in various debris, cores, and fragments of bifacially retouched artifacts.

This assemblage was analyzed under 3 different parameters in order to perform an integration of data in the discussion and interpretation of this evidence: technological analysis, statistical analysis, and analysis of use-wear. Due to the excavation methodology[5], the lithic elements were not coordinated and were simply associated directly to the layer where they were recovered.

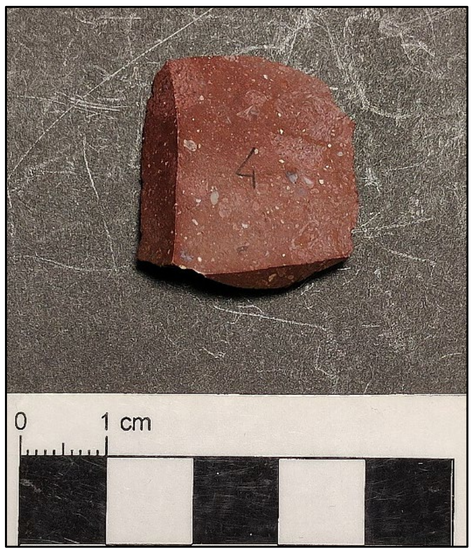


Photo 5 Example of the labeling on the lithic pieces.

Initially the pieces were labeled with a unique consecutive number which was defined by the following criteria:

- Excavation: original pit where the artifact was recovered.
- Level: an approximation of the level where the piece was identified (only for diagnostic elements, such as assemblages associated with different remains of interest like human burials or vessels).
- Layer: stratigraphic layer where the material was identified (each layer had a unique consecutive number for the 3 different excavations carried out, starting from consecutive no. 1 and ending with no. 20).
- Bag number: consecutive and unique labeling for each bag where the pieces were packed.

[5] Exploratory pits of 1x1 meter area and 1m - 1.3m deepness - excavated following stratigraphic levels.

- ID: Each piece in the bag was assigned a consecutive number starting at number 1.

Finally, and for better control and registration of the pieces, each one was marked with the consecutive ID (Photo 5).

4.1 Technological analysis

The technological analysis was applied to the totality of the worked sample. According to Inizan and collaborators (1999), technology can be understood as a conceptual approach to material culture, based on the study, understanding and interpretation of the gestures framed within a technical system used for the construction of such material culture. This is why technology not only encompasses the study of the transformation of natural blocks of rock into tools, but also includes the study of the ideas and decisions that influence the manufacturing process (Andrefsky Jr, 2008; Inizan et al., 1999; Lemonnier, 1992).

Based to the previous, the reconstruction of lithic manufacturing processes is possible through the study of methods and techniques used in this activity. This leads to the obtaining, from the modification of the raw material, of lithic products (which can become predetermined) either by *debitage* or *façonnage* (Arzarello et al., 2011; Inizan et al., 1999). The first consists of breaking a block by means of some technique (e.g., percussion or pressure) in order to obtain different supports that can become cores, debris, or tools (Arzarello et al., 2011; Inizan et al., 1999). The second refers to a succession of carving operations whose main objective is the fabrication of a particular object generating only carving debris and the premeditated artifact (Arzarello et al., 2011; Inizan et al., 1999). To these two terms must be added *retouching*, which refers to the extractions obtained by percussion or pressure with the intention of giving a particular shape to the worked piece.

To determine the technological aspects of the pieces, the following variables were considered:

Measurement: the measurement of the lithic pieces was done with the box method (see Figure 11): length, width, and thickness.

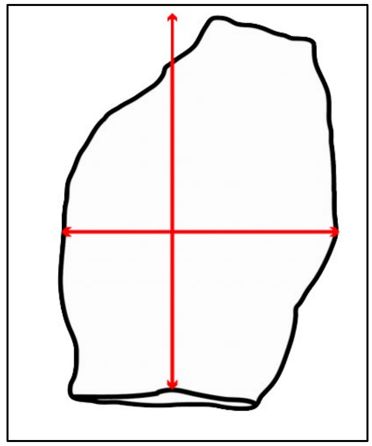


Figure 11 Box method: Length is the maximum distance from the point of percussion to the distal end, following the axis of percussion (perpendicular to the striking platform width). Width is taken perpendicular to the length, at the mid-point of the length (take from Dogandžić et al., 2015, *and modify by the author.*

4.1.1 Raw material:

More than 97% of the total sample is composed of volcanic rocks of the ignimbrite type with an important composition of rhyolites, which have had their genesis in various volcanic and pyroclastic events in the region.

Most of these volcanic rocks share physical characteristics such as their high degree of crystallization, shiny and smooth surface, and excellent conchoidal fracture. This particularity suggests a recurrent supply in the same quarry (either primary or secondary). However, these rocks differ in the various shades of colors in which they are composed. This, according to some geologists who have worked in the area(Buriánek & Hradecký, 2011; Saginor, 2008), may be due to different volcanic events in the region. This means that the genesis of the different shades of these rocks may be associated to particular volcanic events. This statement deserves a much more detailed and profound discussion/research.

A particularity in this rock is that being an ignimbrite it should present a porous matrix, since this rock is generated by the volcanic explosion and the rock flow that forms and transforms an agglomerate of rocks and minerals which are melted by the high temperatures of the volcanic explosion. This genesis gives it the characteristics of agglomerates (porous matrix, heterogeneous, aggregates of other rocks or minerals). However, the archaeological sample is all highly crystallized, which gives it positive properties for carving. This high crystallization of the lithic sample suggests that the ignimbrite has been exposed to an important post-depositional process, which has provided a high crystallization to the ignimbrites that can be registered in the Central American region, must particularly on the Chontales region, Nicaragua.

From this, several questions arise:

- How were these rocks altered?
- Have these rocks undergone hydrothermal alteration?
- Has this hydrothermal alteration enriched the sample in silica?

One of the interpretations to this particularity of the ignimbrites has been proposed by several geologists (Ball et al., 2013; Buriánek & Hradecký, 2011; Mcbirney & Weill, n.d.), who have suggested that post-depositional processes associated with hydrothermal fluids may be the influence of such changes.

For the present investigation it was determined to classify the ignimbrites according to the types of colors identified, however it is clear that all these rocks share several physical characteristics. The ignimbrites were divided into a total of 7 different types, which vary strongly in the colors of their matrices (see Table 6).

4.1.2 Knapping method and techniques

For the identification of the knapping methods and techniques, the Inizan and collaborators (1999) proposal will be followed. For this purpose, it was determined to characterize the following characteristics of the debris:

- Presence of cortex: Absent, total, proximal lateral, mesial, distal or diverse.
- Bulb type: Pronounced, diffuse and absent.
- Type of heel: cortical, flat, dihedral, faceted, winged, linear, pointed or "oté".
- Direction of the negatives on the dorsal face: unipolar, bipolar, centripetal, convergent, or crossed.

Once these variables were characterized, the aim was to establish the knapping technique used (direct percussion with hard/soft hammer, indirect, etc.). On the other hand, we also sought to identify whether the products observed consisted of retouched flakes, the type of support used. Regarding the retouched pieces, these were characterized by determining:

- **Retouch location**: distal, mesial, proximal, lateral (right/left) or basal.
- **Retouch extension**: short, long, invasive, covering.
- **Position of the retouched**: direct inverse, alternate, alternating, crossed or bifacial.

Once the retouches were characterized, we sought to assign a typological category to the piece.

Finally, the types of unintentional accidents of the pieces were recorded, such as fractures during carving and fractures due to post carving processes (e.g., breakage due to falling of the piece). Intentional thermal modifications applied to the pieces were also recorded.

4.2 Statistical analysis

As mentioned in the previous section, the general investigation only considered the lithic materials recovered in excavation sections 2 and 3. Although all the elements present in these sections were technologically analyzed, a representative sample was defined for the statistical analyses that sought to study the technological variability, which was established following different parameters.

Since the nature of this research seeks to make an initial approach to the composition of a lithic assemblage from the Robeto Amador site, a series of variables were established that the elements to be studied had to comply with to be part of the statistical sample. First, it was decided to use only the elements of the most representative layers of the two archaeological excavations, which were layers 2, 15 (ex. 2), 12, 14 and 16 (ex. 3).

Once the layers of major interest for the statistical analysis had been identified, the sample was selected. This selection was guided mainly by the complete integrity of the pieces, leaving aside any elements that were incomplete or fractured. The reason for this was the possibility of performing metric analysis on these pieces. Likewise, the instruments made on flakes were left aside due to two reasons: they have a low frequency of occurrence (n=9) and most of the pieces are fracture.

At the end and after the sample purification for statistical analysis, 427 flakes (complete), 42 cores, and 18 bifacial artifacts (preforms, fractured pieces, complete pieces). A total of 487 elements were obtained from a set of 2059 pieces, distributed in 5 layers and two archaeological excavations. This sample is equivalent to 23.6% of the assemblage.

Once the sample was selected, the most representative technological variables were selected for the statistical analysis. Table 2 shows the database used for the statistical analysis carried out in this research. This frequency table discriminates the lithic pieces recovered by layers/excavations and presents the frequency of occurrence of the different technological variables.

	ARTEFACTS			RAW MATERIAL										BUTT								DIRECTION OF THE NEGATIVES					BULB					
LAYER	**Flakes**	**Cores**	**Bifacial art.**	**A**	**DBR**	**DBRS**	**DG**	**DM**	**DR**	**OBS**	**SB**	**SBB**	**SG**	**Cortical**	**Dihedral**	**Facetted**	**Linear**	**Plain**	**Oté**	**Punctiform**	**Winged**	**Bipolar**	**Centripetal**	**Convergent**	**Crossed**	**Unipolar**	**Absent**	**Diffused**	**Not pronounced**	**Pronounced**	**TOTAL**	**%**
2	44	5	0	0	6	3	0	0	4	0	12	18	1	0	9	1	3	24	3	1	3	3	0	8	10	23	10	20	0	14	**44**	10,30
15	19	8	0	0	5	0	0	0	0	0	9	5	0	0	1	0	2	12	0	2	2	0	2	3	0	14	4	10	0	5	**19**	4,45
12	37	19	1	0	13	3	2	5	2	0	11	1	0	0	3	4	0	21	3	5	1	2	6	5	8	16	0	22	10	5	**37**	8,67
14	219	3	12	4	83	23	4	3	16	1	42	40	3	1	12	24	18	143	6	12	3	13	28	44	59	75	41	128	0	50	**219**	51,29
16	108	7	5	0	27	16	2	0	12	0	30	20	1	3	9	12	13	65	2	4	0	7	5	18	34	44	21	49	0	38	**108**	25,29
TOTAL	**427**	**42**	**18**	**4**	**134**	**45**	**8**	**8**	**34**	**1**	**104**	**84**	**5**	**4**	**34**	**41**	**36**	**265**	**14**	**24**	**9**	**25**	**41**	**78**	**111**	**172**	**76**	**229**	**10**	**112**	**427**	100
%	87,7	8,6	3,7	0,9	31,4	10,5	1,9	1,9	8,0	0,2	24,4	19,7	1,2	0,9	8,0	9,6	8,4	62,1	3,3	5,6	2,1	5,9	9,6	18,3	26,0	40,3	17,8	53,6	2,3	26,2		

Table 2 Frequency of the lithic pieces and the technological variables.

4.2.1 Methods

Since this statistical study focuses on exploring the relationship between debris and bifacial tools, and the morphological and technological variability at the layer and excavation level, the general frequency data presented in the previous section, as well as the metric tables[6], will be used. These relationships of similarities/differences or groupings were explored by means of descriptive statistics and univariate and multivariate analysis.

Prior to conducting any statistical analyses, an important step was transforming the entire database into percentages. This was necessary because some variables had a significantly higher frequency than others, which could lead to misinterpretation. Therefore, to avoid these errors and maintain the integrity of the data, each variable was worked as a percentage. The decision to transform the data was made after running several multivariate analyses with the raw frequencies, which revealed that the high number of frequencies in certain variables modified the interpretation of the database. It is important to note that this transformation to percentages was not applied to the metric analyses.

The statistical analysis consisted of three types of analyses. The first type aimed to provide a general overview of the sample using descriptive statistics, which were calculated using the general table. The second type of analysis focused on investigating the variability in morphology and technology at the layer level. Lastly, the third type of analysis aimed to explore the variability between debris and bifacial tools.

In the second type of analysis, the first step was to construct metric tables that group all of the lithic artifact measurements. Additionally, tables were created that show measures of central tendency (such as the median) and their corresponding measures of dispersion (such as the Inter-Quartile Range). To explore these measures, dot plots and multivariate factor analysis (PCA) were employed. In some cases, it was necessary to transform the data to give it a more normal distribution. This transformation was performed to achieve greater precision in exploring the relationship between variables when applying parametric tools.

A second analysis focuses on studying the technological variables that are directly related to the presence of bifacial instruments. To accomplish this, a correspondence analysis will be conducted with all the variables, including the variable of bifacial instruments. This analysis aims to understand how these variables are related to each other.

Finally, it should be noted that the statistical program used was version 4.12 of PAST: Paleontological Statistics software package for education and data analysis.

4.3 Use – Wear analysis

The functional analysis methodology offers a comprehensive approach to address the problem of the context of use of the lithic materials under study. In this way, a complete vision of the artifactual assemblage is obtained by inferring the function of the artifacts, the material used, and the activities

[6] Metric tables will be presented in the appendix of the thesis.

carried out in a specific context, in other words, how they were used within a social system (Keeley, 1980; Lemonnier, 1992; Leroi-Gourhan, 1993; Mansur-Franchomme, 1986, 1999). The proposed method is based on three essential pillars: 1) the development of an experimental program, 2) the observation and characterization of the traces formed on the blades of the instruments due to their use in the processing of different materials (see Result Chapter), and 3) the comparative analysis of the archaeological collections with the experimental results (see Result Chapter). For this purpose, a study methodology was integrated to observe lithic artifact edge macroscopically (low power approach) and microscopically (high power approach).

To develop the reference collection, an experimental protocol was defined which sought to address the variables (direct and indirect) that will allow the generation of the use traces of the lithic artifacts.

4.3.1 Experimental protocol for the studying of the lithic assemble from Roberto Amador, Nicaragua. First approach from the use-wear traces analyses.

- **Objectives of the protocol:**

Once the technological analyses on the lithic assemblages were done, and a bibliographic reviewed of the archaeological area and subject was carried, some hypotheses arose about the use of space that are intended to be addressed from the traceological study:

Hypotheses And Ideas About Roberto Amador Archaeological Site:

- Local hypothesis and ideas:
    - The excavation report of the RA site shows that the lithic assemblage was related with other types of cultural material. Materials such as foreigner and local pottery, and one funeral vessel with human remains was found in the same context of the lithic assemblage (*Ex. 3*-top of the terrace-). This complex stratigraphy allows the researchers to interpretated the top of the terrace as a burial area (Torreggiani, personal communication). Nevertheless, the technological analyses on lithic suggest and need different explanations:
        - Why a lithic workshop was setup near a burial area? there is any link between these two events?
        - Lithic workshop:
            - We expect a very low use of lithic manufacture.
            - The technological analysis evidence a continuum in the lithic production during the three main layers of the excavation. The abundance of not finished bifaces, or bifaces broken in the last stage of manufacture support this idea.
        - A common use of the space (living, workshop, burial). As an example, in the prehispanic communities of the northern part of South America was very

common for relatives to be buried within the residential areas (Rodríguez Cuenca et al., 2006). This practice has been interpreted as an invitation to the dead to continue inhabiting their spaces.

The final objective of this protocol is to provide data that allows discussing the hypotheses raised above from the perspective of the analysis use-wear of the lithic ensemble of the Roberto Amador site. For this, several phases will be developed:

The first will be the creation of an experimental program which will seek to recreate the RA lithic assemblage, following the same technical and technological guidelines identified during the technological analysis. After the creation of this experimental set, it will be subjected to different use tests on materials previously identified as raw materials worked by the pre-Hispanic groups of the area.

The second phase will be the observation under different microscopic magnifications of each of the edges used during the experimentation in order to identify and characterize each of the use-wear traces that were caused by the different materials worked in combination with the different gestures that manipulated the instruments.

The idea of this work is to create a reference collection of the different use-wear traces that can occur in the lithic assemblages of the Roberto Amador site, Chontales region, Nicaragua. This reference collection will allow us to compare the different traces identified in the lithic pieces from the RA site with those of the experimental collection to identify and characterize them to give them an interpretation under a larger archaeological data context.

Below are the steps that this protocol will follow:

1. **Selection of the archaeological sample.**

The selected archaeological material belongs from the two pits located over the Roberto Amador Site, one halfway up the slope of the terrace (*Ex. 2*) and the other on the top of the terrace (*Ex. 3*). The selection of the archaeological sample to be analyzed was carried out following two criteria.

- The first was a selection of flakes that had a particular morphology. This group of pieces with certain macroscopic morphological characteristics that would allow them to suggest a possible use of the flakes were sampled.
  - Those flakes that presented an adequate apprehension for use as instruments, also that presented functional edges and with possible macroscopic traces that evidenced use (edge damage), were randomly selected.
  - All blades or fragments of blades were selected for analysis. This is due to particularly contrasting the hypotheses that seek to identify the function of these lithic reduction sequences.

- A second criterion for selecting a second group of flakes was carried out by a random sampling, resulting in flakes with different sizes which will be analyzed under the microscope in order to identify possible traces.

A total of 10% of each lithic assemblage was selected for analysis (considering the random and selected sample). This selection present 32 elements for the Ex. 2 lithic assemblage and 202 elements for the Ex. 3 lithic assemblage for a total of 234 elements for the use wear analysis.

2. The experimental assemblage

The importance of experimental programs within archaeological studies has become a basic and necessary tool to obtain a better correlation between the hypotheses raised and the cultural remains studied (Bamforth, 2010; Lerma, 2008; Marsh & Ferguson, 2010; Outram, 2008; M. J. Shott & Sillitoe, 2005). Also, to understand the past its necessary to assume that there are certain rules of the present that rule the past (Stout, 2002). To achieve a correlation between the latter, it is necessary to design a structured experimental program that is focused create a correct dialogue between the hypotheses, the variables to be studied and the analogies that they will be made on the archaeological remains(Lerma, 2008; Outram, 2008). Regarding this, in the last decades the *controlled experiment* has become more popular in experimental archaeology due to it interpretative capacity (Eren et al., 2016). These types of experiments are characterized by testing different individual variables and understanding the interaction between them (Eren et al., 2016). This experiment protocol will use this guideline.

Photo 6 Production of the experimental assemblage. University of Ferrara, Experimental archaeology classroom. 2022. (left) Direct percussion and (right) indirect percussion -pressure-.

- **The knapping manufacture.**

The production of the experimental set of flakes sought to follow the same lithic reduction sequence identified during the technological analysis of the lithic set from the Roberto Amador site. For this, two lithic reduction sequences were performed: the first focused on obtaining a bifacial instrument/flakes, and a second reduction focused on obtaining blades, both similar in shape to the RA products (Photo 6). Regarding the raw material, the knapping work was done over a block of obsidian form the Mediterranean volcano of Lipari-Italy for the manufacture of the blades, and on hydrothermal flint (McBirney & Weill, 1966) belonging to the Chontales region, Nicaragua for the bifacial reduction sequence.

The knapping of the experimental assemblage was made in November of 2022 on the University of Ferrara. During the manufacturing process, certain problems appeared that creates some difficulties to carry out the experimental knapping. The first and main one was that the hydrothermal flint block presented a series of an inside crack that prevented obtaining the “ideal conchoidal flakes”. This is supposed a problem for the manufacture of a final product of the bifacial type.

Regarding the flakes, it was possible to obtain a set of 30 flakes with morphologies like those identified in the archaeological complex and of which 23 pieces were chosen to be worked on different materials (Table 3).

Each flake where registered in a form (see Figure 12) where the information related to morphology, technology, and the recording of the different changes presented before and after the use of each flake (for the experimental ones) has been recorded. For the objectives of this protocol is very important to develop a very precise and detailed set of images that illustrate the different edge modifications that where develop by the active edges worked with the experiment. That’s why each experimental flake will be graphically recorded before and after the experimental use for understanding the production of the use-wear traces. In particular, the active edges that where the object of the experiment work, will be recorded in detail with the help of different microscopy zooms (stereoscope and metallographic).

Gesture/material	**Dry Wood**	**Fresh Bone**	**Vegetable sample -Pumpkin-**	**Fresh Meat**	**Fresh Skin**	**Antler**
Longitudinal unidirectional cutting	1 (8[7])	1 (11)	1 (30)	2 (19-13)	1 (18)	1 (16)
longitudinal bidirectional sawing	1 (17)	1 (22)	1 (21)	1 (10)	1 (20)	1 (12)
Transversal unidirectional	1(4)	1 (2)	1 (28)		1 (9)	1 (27)
Transversal bidirectional	1 (1)	1 (5)	1 (31)		1 (24)	1 (15)

Table 3 Distribution of the experiment carried out with the experimental samples. It contains the type of gesture made, the type of material worked, and the number of flakes worked and inside parenthesis the number of each flake.

[7] The number inside the parenthesis is the experimental seriation.

<table>
<tr><td colspan="4">International Master in Quaternary & Prehistory
University of Ferrara
Use-wear experiments</td></tr>
<tr><td>Name of the operator:</td><td>Place:</td><td>Date:</td><td>Tool No.:</td></tr>
<tr><td>Raw material:</td><td>Knapping Technology:</td><td colspan="2">Knapping Technique:</td></tr>
<tr><td>Worked material:</td><td>Type of Gesture:</td><td>Activity:</td><td>Duration of use (minutes):</td></tr>
<tr><td colspan="4">Description of the flake
L x l x S:
Type butt:
Number of useful edges:
General observations:</td></tr>
<tr><td colspan="2">Scheme of the product (Draw of the product, Pointing the useful edge, Some general observations):</td><td colspan="2">Scheme of the product after use (General descriptions of the tool after the used. Draw a scheme of the use-wear traces):</td></tr>
<tr><td colspan="2">Macro traces observed</td><td colspan="2">Micro traces observed:</td></tr>
</table>

Figure 12 Form used for register the experimental flakes and the archaeological samples.

3. Experimental work over diverse materials

The aim in this experimental work is to obtain a reference framework of use-wear traces to have a more precise interpretation for making analogies between experimental and archaeological samples. Even though there are several gestures to perform tasks with lithic instruments (Keeley, 1980; Gutiérrez, 1990; González & Ibáñez, 1994), this protocol will only consider 2 different gestures, longitudinal and transversal ones[8].

The experiment will search a standardized scope to create different traces by working flakes in different materials and with different gestures. For this, each flake was worked 15 minutes on a particular material (Table 3).

After the use and before the microscopic analysis each flake will be cleaned by using an ultrasonic tank filled with a mild solution of dishwashing liquid and distilled water for 3 minutes; consequently, the pieces will be rinsed with distilled water and 70% alcohol; finally, they will be dried on paper towel.

4. Microscopic analysis

This research will use “low power approach” and “high power approach” for the analysis of the experimental and archaeological assemblage to develop a detailed database about the observable

[8] In the next chapters these concepts are developed.

traces in the experimental and in the archaeological assemblage. These two different approaches are going to be used in combination, because each offer particularly advantages:

- **Low Power Approach**: bases its analysis on the use of low magnification microscope lenses (binocular loupes), which do not usually exceed 80x magnification. These increases have 2 advantages; The first is that it allows a large-scale analysis to be carried out in a short period of time, which translates into much lower costs and study times for a study; the second, presents a simple, fast identification and quite acceptable identification with regard to the study of variables such as edge damaged and the identification of active zones in the edges (Tringham et al., 1974; Odell & Odell-Vereecken, 1980; Odell, 1981).
- **Hight Magnification Approach**: bases its analysis on the use of microscopic lenses with magnifications that used to exceed the magnification at least 200x (usually a metallographic microscope). Different series of experiments have demonstrated that the high magnification approach has a greater confidence for the interpretation of the use-wear traces (Keeley, 1980).

Although each microscope has advantages and disadvantages over the other, the complementarity between the two presents the most advantages when interpreting use-wear. Even though this postulate was present since the publication of Keeley's work in the 80´s, few authors in the 80s and 90s used both magnifications for traceological studies (Grace, 1996). Since then, this complementarity in the increases has been increasingly common to the point of being undisputed, thus achieving the generation of different analysis protocols capable of generating greater precision in the results, for example: (Berruti & Daffara, 2014). Since the beginning of the millennium, microscopy analyzes have gone further, incorporating electron microscopes into their analyzes, thus obtaining a higher resolution in the traceological data obtained. (Álvarez et al., 2012; Borel et al., 2014; González & Ibáñez, 2003; Hernando et al., 2020; Martín-Viveros & Ollé, 2020; Ollé & Vergès, 2014).

The first moment of analysis will be made with binocular loupes or stereoscope (*Leica LAS EZ4 HD* - 8x-35x magnification). This step in the analysis will mainly seek to identify the work areas, as well as carry out a basic and general characterization of the variables of type of gesture, edge damage and polish when it appears and can be observable on low scopes.

The second moment in the microscopic analysis will be done by metallographic microscope *Optika B383 MET* (50x-500x magnification) with reflected light and digital camera *Optika B3*. This high magnification analysis will seek. The objective of this high magnification analysis is to make a detailed description of the dependent variables (sensu González & Ibáñez, 1994) and to be able to characterize them in the most detail way[9]. Also, a graphic record of the area with this microscope will be done (Grace, 1996; Keeley, 1980).

Once the analysis has been carried out under the microscopes, and the recorded traces of use have been characterized, an interpretation of these traces will be carried out. As has been rectified throughout different investigations, functional analysis is not yet an accurate methodology to determine all the aspects required for the use of archaeological instruments. However, it can bring

[9] For Reading the characterization of the variables taken, read the chapter 2.

us closer to the interpretation of certain qualities surrounding the use of stone tools, such as determining if a tool was used, what hardness of material was used and, in certain occasions, the direction in which the tool was used.

Material used: for this purpose, a table of worked materials by type of hardness was generated. This table was based on the previous works of Keeley (1980) and Odell and Odell (1980), who have assigned a type of hardness to different materials worked in stone (see Table 1). This is why each archaeological piece, depending on the type of traces, will be assigned a category of worked material:

- Soft
- Medium Soft
- Medium Hard
- Hard
- Indeterminate: this category implies the presence of traces of use that do not allow the identification of the type of material worked.

Kinetic movement: the kinetic movement allows us to determine the way the piece is used, and this category is given mainly by the grooves/striae and their directions, and in certain occasions by the directions of the polishing:

- Longitudinal unidirectional
- Longitudinal bidirectional
- Transversal unidirectional
- Transversal bidirectional
- Mixed: with marks that indicate longitudinal and transversal movements
- Indeterminate: parts that show traces of use, but it is not possible to identify the kinematics of movement in use.

Once the presence or absence of traces on a piece has been recorded, these will be assigned a category of use following the methodology proposed by Pal (2012), who has determined 3 categories for those tools that presented traces of use:

- **Piece with certain use (PCU):** they present traces that allow to identify with certainty the worked material and the gesture. The pieces that present just macro traces (edge removal) will be classified as PCU. This is due to the impossibility of relying on the edge removals origin (see the discussion on the Methodological approach).
- **Piece with probable use (PPU):** they present poorly developed traces of use. For these pieces it was not possible to identify the worked material and/or the movement. The pieces that present any type of micro traces (polish, striae or rounding edge), will be classified as PPU.
- **Piece not used (PNU):** they present an absence of any macro or micro traces of use.
- **The variables for analyze with the microscope[10].**

[10] For broader discussion, see the section of the different approaches in the methodology of footprint analysis in this chapter.

The traceological study intrinsically requires an experimental program that allows scientifically contrasting the hypotheses raised in archaeological research (Outram, 2008; Eren et al., 2016; Marreiros et al., 2020). Throughout the experimental program, the behavior of stone artifacts during their use on different work materials must be studied and recorded. This activity should generate not only empirical knowledge about the performance of these artifacts, but also generate a frame of reference data about the traces of use-wear on the worked edges of the stone tools. It is necessary to control the variables that intervene during the experiment (Outram, 2008). In this regard, the type of variables that are involve during the realization of a program of experimentation of traces of use have been defined. For read about independent and dependent variables, check in the previous pages.

5. Analysis of the archaeological sample

The analysis of the archaeological sample will be carried out following the same scheme with which the experimental samples were analyzed. At first, they will be observed with low magnification binocular loupes to observe mainly Edge damage on the edges of the flakes. Likewise, with this modality it is also possible to observe and record certain types of polish. These macroscopic morphological changes will be recorded on the same form in which the pieces were recorded (Figure 12).

The second part of the analysis will be developed using a high-magnification microscope (metallographic) which will be focused mainly on the search for possible polishing, polish, and grooves (González & Ibáñez, 1994). These macroscopic morphological changes will be recorded on the same form in which the pieces were recorded (Figure 12).

Once a possible use-wear trace is identified, it will be described in detail to determine characteristics such as the type of gesture and type of material used. This will be done using the images taken on the set of experimental flakes as a reference collection.

5 Results

As mentioned in previous chapters, the present investigation focused on the analysis of the lithic material corresponding to excavation No. 2 and 3. These two excavation pits had an area of 1x1 m2, and a relative depth of 1.3 m for the first one, and 1 m for the second one. A total of 2059 lithic pieces were recovered for both pits, which were classified following the methodology presented in chapter 2. This lithic assemblage was analyzed in three different ways; first, in a techno-morphological way, secondly, the traces of use were analyzed with the help of optical magnification with the support of an experimental program. Finally, the sample was explored under a statistical approach to look for possible correlations to explore the data independently.

The general data and the results of the techno-morphological, statistical and traceological analyses, as well as the data recovered during the experimentation, are presented below.

5.1 Technological result

As mentioned in previous chapters, the present investigation focused on the analysis of the lithic material corresponding to excavation No. 2 and No. 3. These two excavation pits had an area of 1x1 m2 each, and a relative depth of 1.3 m for the first one, and 1 m for the second one. A total of 2059 lithic pieces were recovered for both pits, which were classified following the methodology presented in chapter 2. The general and particular results of the technological and traceological analyses developed in the research are presented below.

5.1.1 Excavation No. 2

The excavation No. 2, corresponding to the middle slope of the terrace of the Roberto Amador archaeological site, revealed a total of 6 stratigraphic units of which only 3 presented lithic material with a total of 357 pieces which were technologically analyzed. Stratigraphic unit 2 showed the highest presence of stone items with a total of 58.5% of the sample, followed by units 15 with 37.8% of elements and unit 17 with a total of 3.6% of the sample (Table 4).

EX. 2

STRATIGRAPHICAL LAYER	Pieces	%
2	209	58,5
15	135	37,8
17	13	3,6
TOTAL	357	100,0

Table 4 General distributions of the lithic assemblage Ex. No.2

The lithic artifacts from excavation No. 2 are mainly represented by lithic products with 94.7% (338 pieces) of the sample, while cores have a representation of 4.8% (17 pieces) and 0.6% (2 pieces) of elements with retouches were reported, among which some instruments stand out (Table 5).

At this point it is important to mention that this pit showed a distribution of frequencies in raw materials quite uneven. Due to this distribution, it was only possible to generate technological trends for those artifacts worked on silicified ignimbrite rhyolite, which is the raw material most represented in the pit, comprising 98% (350 pieces) of the sample. The presence of raw materials such as silex (1.7%) and volcanic rocks (0.3%) was also reported. For these last raw materials, no descriptive technological trends were generated due to their low frequency of occurrence.

ARTEFACT	PIECES	%
INSTRUMENT	**2**	**0,6**
BLADE	1	
INDETER.	1	
CORES	**17**	**4,8**
FLAKES	**338**	**94,7**
BLADE	9	2,7
FLAKE	55	16,3
INDETER.	274	81,1
TOTAL	359	**100,6**

Table 5 General distributions of the lithic assemblage Ex. No.2

RAW MATERIAL EX. NO.2

RM	Pieces	%
IGNIMBRITE RHYOLITE	**350**	**98,04**
TYPE 1	84	24,00
TYPE 2	19	5,43
TYPE 3	10	2,86
TYPE 5	28	8,00
TYPE 6	88	25,14
TYPE 7	121	34,57
FLINT	**6**	**1,68**
A	2	33,33
SG	4	66,67
VOLCANIC	**1**	**0,28**
BG	1	100,00
TOTAL	357	100,00

Table 6 Distribution of the lithic raw material on Ex. No.2

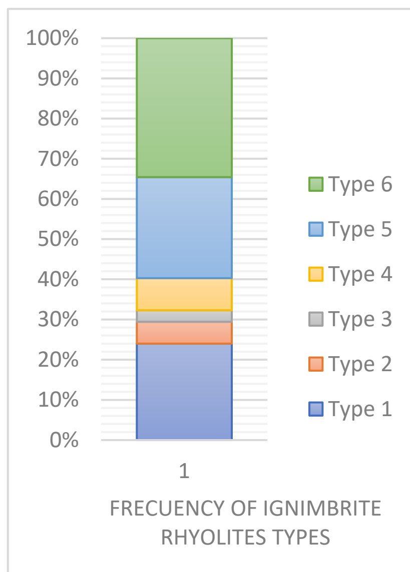


Figure 13 Distribution of the frequency of raw material on Ex. No. 2

However, it was possible to observe certain variability in the indiscriminate use of silicified ignimbrite rhyolite, which was classified into different types, following physical characteristics such as color. In this respect it can be said that type 6 was the most used ignimbrite rhyolite, followed in a fairly similar frequency by types 5 and 1 (Table 6).

5.1.1.1 Technological description

As mentioned above, the artifacts from pit No. 2 are distributed in 3 different layers. However, due to the low frequency of material reported for layer 17 (3.6% - 13 pieces), it will not be described. The following are the distributions and technological trends identified for two of the upper layers of the pit, layer 2 and 15:

5.1.1.1.1 Layer 2

The state of preservation of the recovered elements is an important characteristic for the evaluation and technological analysis of the pieces since it will allow us to identify the presence of the technological characteristics. For layer 2 it was identified that most of the pieces were represented by distal fragments, followed by quite similar frequencies of complete pieces and proximal fragments. It is important to note at this point that the technological analysis was carried out on all the recovered pieces, and the technological characteristics that could be obtained from each of the flakes were recorded, provided that the integrity and characteristics could be observed (Figure 14).

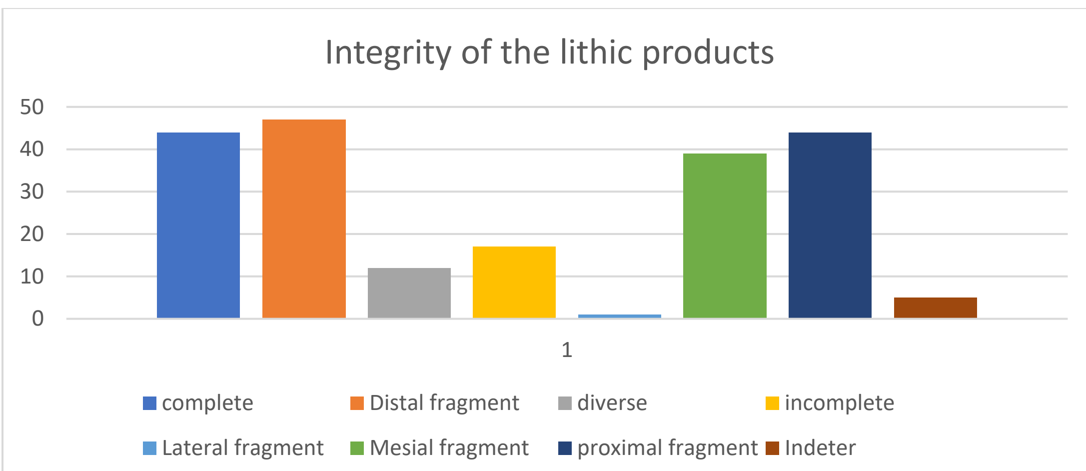


Figure 14 Integrity of the lithic products Layer 2 – Ex. No.2

Within the category of lithic products, it is important to highlight the state of integrity of the these because this state will allow us to carry out detailed or particular analysis of the reduction sequences observed. Particularly for this assemblage, it was possible to observe two types of lithic products, flakes, and blades (Inizan et al., 1999).

A 94.7% (198 pieces) of the sample presented a total absence of cortical surfaces or cortex, which suggest the link in the reduction sequence of the lithic collection. For the remaining 6.3% of the sample, the most representative values are the pieces with a total cortex on the reverse with 1.9% (4 pieces), and pieces with a coverage of one of its sides with a representation of 1.4% (3 pieces).

For the rest of the categories (distal, mesial, and proximal), one representative piece was presented for each one.

On the other hand, the butt could only be observed in 51.2% (105 pieces) of the recovered pieces, the rest of it were fractured in such a way that it was impossible to identify the presence of this technological characteristic. Of the remaining pieces, the most representative butt was the smooth type with 41% (43 pieces), followed by a faceted type represented by 22.9% (24 pieces) of the sample. The next group of typical butts is given by the dihedral 9.5% (10 pieces), "oté" 8.6% (9 pieces), pointed 7.6% (8 pieces) linear 5.7% (6 pieces) and finally the winged with 4.8% (5 pieces) of representation of the sample. It is worth mentioning the high representation of butts suitable for a delicate formalized knapping for a complex manufacture, such as a bifacial or a laminar debitage (Andrefsky Jr, 2008; Arzarello et al., 2011; Inizan et al., 1999).

The presence of bulb in the flakes was only identified in 51.2% (105 pieces) of the total sample. In the remaining pieces, due to different types of fracture, this characteristic could not be recorded. Of the total number of bulbs recorded, 50.5% (53 pieces) belong to the intermediate category of diffuse bulbs, and the remaining two parts share 22.4% (26 pieces) for pronounced and absent bulbs.

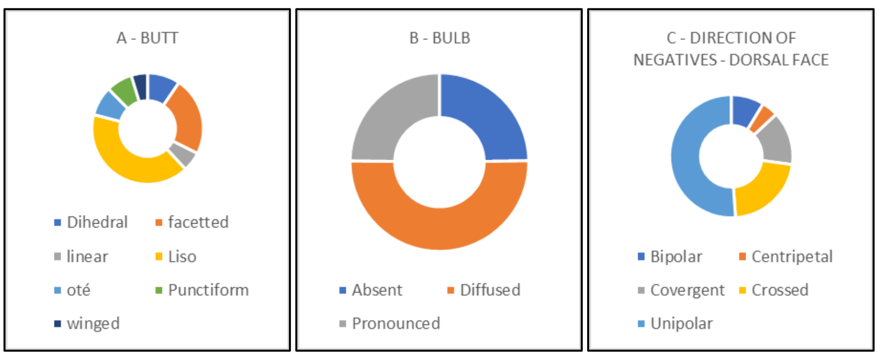


Figure 15 Graphics of the technological characteristics on the layer 2 – Ex. No. 2: A – Butt; B – Bulb; C – Direction of the negatives – Dorsal face.

Finally, it was possible to identify in 44% of the total sample (92 pieces) the direction of the negatives on the dorsal face. This attribute allows us to recognize the intentionality and the direction in which the lithic reduction of the product is being focused. The negatives on the back in pit No. 2 presented a unipolar direction in more than half of the sample represented with 51.1% (47 pieces), followed by a crossed direction 21.7% (20 pieces), convergent 14.1% (13 pieces), bipolar 8.7% (8 pieces) and finally, a centripetal direction with 4.3% (4 pieces).

Regarding unintentional accidents and intentional modifications, it can be said that a total of 25.8% (54 pieces) presented unintentional fracture during knapping, being the most common accident in the sample of pit No. 2, followed by "hinge termination" accidents represented by 2.3% (5 pieces), "parasite flake" with 3.3% (7 pieces) and finally, there is 0.9% (2 pieces) of accidents classified as "siret". It was identified that thermal modification is present in the sample, however, its representation is somewhat scarce with a total of 3.3% (7 pieces) with respect to the sample of pit No. 2.

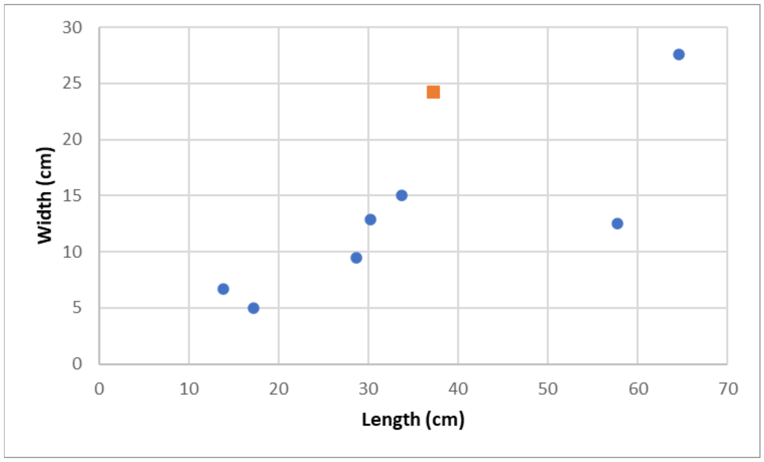


Figure 16 Comparation between blade and blade cores dimension of the layer 2 – Ex. No.2.

A particularity of the layer 2 and in general of pit No. 2 is the absence of bifacially retouched pieces (complete or incomplete). However, the type of evidence exposed by the recovered flakes suggests a similar production to that identified in pit No. 3, but with the clear presence of a sequence of lithic reduction of laminar type. In this regard, it can be said that, of the 5 cores identified, 1 piece could be classified as a laminar core (20%). On the other hand, it should be noted that the presence of lithic products classified as laminar was represented by 7 specimens. But if it is observed in comparison with the total set of products, represented by a universe of 202 specimens of which 159 presented a fractured integrity (not found complete) and 37 complete flakes, it can be understood that the representation of blades is 14.8% in the representative sample of knapping lithic products of complete integrity[11].

It is also important to highlight the metrics of the complete pieces associated with laminar lithic reduction. If we compare morphometrically the sizes of the exploited faces of the cores and flakes (length x width), we can understand that the only identified core still had the capacity to continue to be exploited (see Figure 16).

5.1.1.1.2 Layer 15

The lithic artifacts from layer 15 are mainly represented by flakes with 97,8% (132 pieces) of the sample. On the other hand, cores have a representation of 2,3% (3 pieces) and no elements with retouches were reported. About the cores its important mention that these were catalogue as amorphous cores, with multidirectional negatives around them.

[11] This comparison has been made only considering full integrity lithic products.

ARTEFACT	PIECES	%
Instrument	**0**	**-**
Cores	**3**	**2,2**
Flakes	**132**	**97,8**
Blade	3	2,3
Flake	16	12,1
Fractured piece	113	85,6
Total	135	**100,0**

Table 7 General distributions of the lithic assemblage Layer 15 – Ex. No.2

Unlike layer 2, this layer presented a different frequency distribution with respect to the integrity of the recovered flakes. The most representative integrity was diverse, which is when the piece is in a high state of preservation but is not totally complete. This category[12] was created in order to differentiate from the complete pieces (to which statistical and morphometric analyses were applied). The following categories were complete, distal, and proximal pieces.

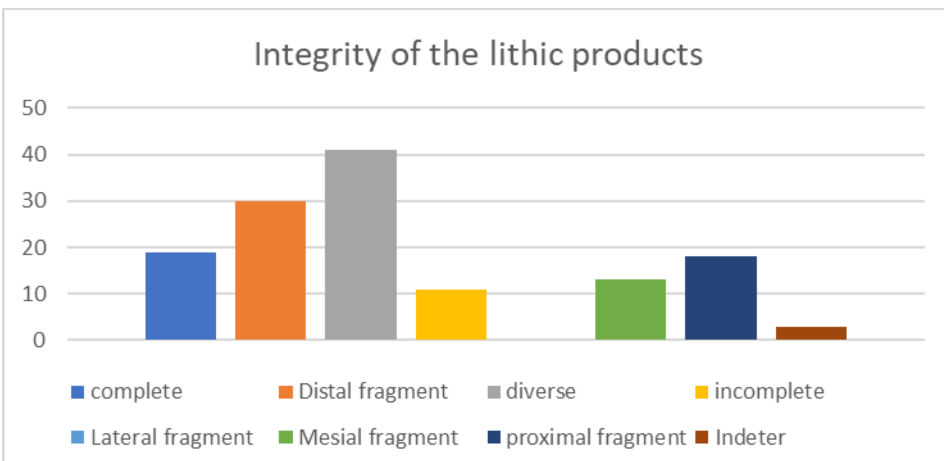


Figure 17 Integrity of the lithic products Layer 2 – Ex. No.2

Like the upper layer, this one presented a high percentage in the frequencies of absence of cortex with 98.5% (133 pieces). Only two pieces presented cortex on the entire dorsal side.

Regarding the butts, the frequencies also behaved similarly to those of layer 2. The most representative butt was the smooth type with 45.8% (22 pieces) of the sample, followed by the faceted butt with 25% (12 pieces). In a third level are grouped the rest of the butts, which had a representation ranging from 6.3% to 4.2% (see Figure 18). As in the previous layer, the relatively high frequency of prepared butts is highlighted, consistent with the presence of a lithic reduction of the *façonnage*/bifacial type.

[12] For see the created categories, see the Materials and Methods chapter.

The presence of bulb in the flakes was only identified in 35.6% (48 pieces) of the total sample. In the remaining pieces, due to different types of fracture, this characteristic could not be recorded. Of the total number of bulbs recorded, 66.7% (32 pieces) belong to the intermediate category of diffuse bulbs, and the remaining two parts again share frequencies with 16.7% (8 pieces) for pronounced and absent bulbs.

Regarding the directions of the negatives, this could be identified in 30.4% (41 pieces) of the sample. Of this group, the most representative frequencies where unipolar with 53.7% (22 pieces), followed by crossed type 26.8% (11 pieces). Finally, and grouped in a similar frequency range, are the convergent type 12.2% (5 pieces), centripetal 4.9% (2 pieces) and bipolar 2.4% (1 piece).

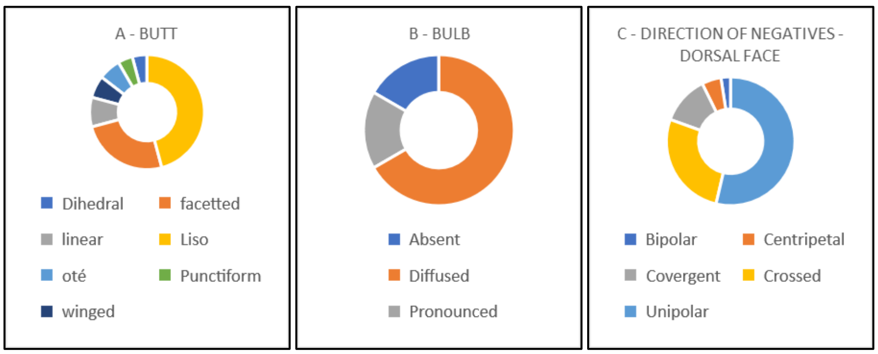


Figure 18 Graphics of the technological characteristics on the layer 15 – Ex. No. 2: A – Butt; B – Bulb; C – Direction of the negatives – Dorsal face.

Regarding unintentional accidents and intentional modifications, it can be said that a total of 14.8% (20 pieces) presented unintentional fracture during knapping, being the most common accident in layer 15, followed by "hinge termination" accidents represented by 5.1% (7 pieces), "parasite flake" with 2.2% (3 pieces) and finally, there is 0.7% (1 piece) of accidents classified as "siret". It was identified that thermal modification is present in the sample, however, the representation of this modification continues to be scarce with a total of 4.4% (6 pieces).

Although the excavation presented a third stratigraphic layer with the presence of lithic elements (Layer No. 17), only a total of 17 pieces were recovered, for which reason the results are not presented beyond the following table:

ARTEFACT	PIECES	%
INSTRUMENT	0	-
CORES	9	69,2
FLAKES	4	30,8
TOTAL	13	100,0

Table 8 General distributions of the lithic assemblage Layer 17 – Ex. No.2

5.1.1.2 Technological Trends

In general terms and according to the bibliographic review, most of the lithic assemblage from excavation no. 2 was manufactured from local raw materials (see the Materials and Methods chapter for the raw material discussion). Although the technological analysis did not present solid evidence on the type of nodules used, it did show a slight tendency to use secondary raw material sources (Terradas, 2001). In other words, the nodules exploited were boulders obtained from the surrounding water flows[13]. This behavior was repeated for the two archaeological layers studied 2 and 15.

According to several lines of evidence such as the morphology of the flakes, the experimentation developed in the research and the archaeological literature (Andrefsky Jr, 2008; Arzarello et al., 2011; Inizan et al., 1999), the knapping technique used was mainly dominated by direct percussion with soft/organic hammer, and to a lesser extent by direct percussion with hard hammer and by pressure for some few retouched flakes identified attesting to the last stages of the lithic reduction sequences identified. This trend was also identified for both stratigraphic layers studied.

Two different lithic reduction sequences were identified in the excavation, and both are present for both layers. One sequence is focus on the blade production and the other to achieve shaping elements, bifacial tools.

- The lithic reduction sequence related to blade production is not complete due to the absence of some adequation stages at the site. The absence of core preparation flakes and the presence of technical preparation flakes (ridge flakes), together with the low frequency of complete flakes attest to two scenarios. First, laminar cores were previously prepared and taken to the area of the excavation No. 2 in order to be exploited by the blade production. Second, the final products of this reduction sequence (blades) were transported to area of Roberto Amador site for it use[14]. Finally, only one core was recovered from archaeological layer 2. This laminar core presented a classic morphology with transverse and longitudinal convexity and measurements that allow it to be catalogued as still productive (see Figure 19). There is no technical explanation for the abandonment of this core.

[13] It should be recalled that according to the geological literature, it is possible to identify the silicified ignimbrites rhyolites in the form of river pebbles.

[14] The traceological analysis was unable to determine any use wear in any product (complete or incomplete) related to the blade reduction sequence.

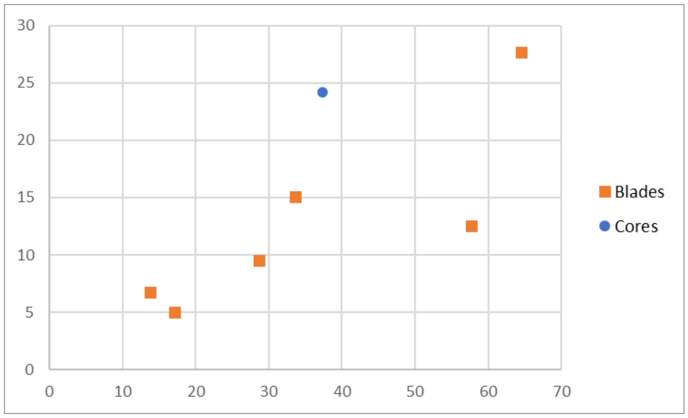


Figure 19 Relation between the measures of the complete blades and the only core found in the Layer 2-Ex no. 2.

- The shaping, unlike the laminar reduction sequence, presents lithic products belonging to different stages of the flintknapping operations for the manufacture of bifacial tools. It should be noted that the presence of this reduction sequence is only attested by the flakes produced by shaping. The total absence of final products, or fragments of them, is one of the characteristics of the two studied layers of excavation 2. Nevertheless, the flakes testify the presence of the distinct phases necessary in the manufacture of a bifacial tool.

  Initially, it is possible to identify, in a low frequency, flakes whose objective was to create a peripheral striking platform. These products were extracted by direct percussion with a hard hammer, although some pieces were recorded that suggest the use of a soft percutor for this same task. These products are characterized by presenting a clean impact point on a butt usually characterized as plain and by having a normally prominent bulb, catalogued as pronounced. These flakes tend to have a higher metric ratio than the rest of the flakes, presenting wide thicknesses and elongated pieces. Another characteristic of these products is their lack of a curved longitudinal profile.

  The second stage, generation of a bifacial equilibrium plane, is represented by flakes extracted entirely by direct percussion with an organic hammer. These flakes are characterized by having prepared and thin butts, with bulbs that are not prominent and have been characterized mainly as diffuse. The width and length measurements of these products tend to be smaller and use to present convexity in the longitudinal profile due to the elasticity given by the knapping with organic hammer. Another characteristic of these products is that the negatives on their dorsal face tend to be convergent and unipolar, which suggests a knapping focused on the roughing and thinning of the piece.

  The third and last stage in the manufacture of a biface is the generation of the bilateral equilibrium plane and is exemplified by products that have been extracted in their entirety by direct percussion technique with an organic percutor. Likewise, these products are characterized by presenting a prepared heel, as well as a very diffuse or absent bulb. These products, due to their purpose of giving the artifact its final morphology, present small sizes that are characterized by a low thickness.

Finally, some flakes that were recover were catalogued as products generated by retouching. These pieces tend to present a similarly small size, but with the difference of presenting a very sharp striking platform angle, as well as small negatives produced in the proximal area of the dorsal face of the piece. The presence of these pieces is very scarce, so it can be interpreted that the retouching or re-sharpening stage did not take place in the area of excavation No. 2, since the frequency of occurrence of these pieces is minimal in both layers.

5.1.2 Excavation No. 3

Excavation No. 3 is located in the upper part of the alluvial terrace of the Roberto Amador archaeological site, presented a frequency of lithic elements much higher than that presented in pit No. 2, reaching a total of 1702 pieces distributed in 5 stratigraphic layers. The frequency distribution is headed by layer 14 with more than half of the total set 52.8% (898 pieces), followed by layers 16 - 23.7% (404 pieces) and layer 12 - 14.9% (253 pieces). In the last level of frequency are layers 18 5.9% (100 pieces) and layer 19 2.8% (47 pieces). These last two layers, due to their low frequency compared to the rest of the layers, will not be considered for the statistical description of your sample.

EX. 3

STRATIGRAPHICAL LAYER	Pieces	%
12	253	14,9
14	898	52,8
16	404	23,7
18	100	5,9
19	47	2,8
TOTAL	1702	100,0

Table 9 General distributions of the lithic assemblage Ex. No.3

At this point it is important to mention that this pit evidenced a quite disparate distribution of frequencies in raw materials. As for pit No. 2, it was only possible to make a trend of material distribution with respect to silicified ignimbrite rhyolite due to its overrepresentation in the sample. This has a presence in 98.1% (1670 pieces) of the recovered pieces. This excavation also showed evidence of infrequent use of raw materials such as silex 1.6% (27 pieces) and volcanic rocks such as obsidian with a representation of 0.2% (4 pieces). For one piece the raw material could not be identified. For these last raw materials, no descriptive technological trends were generated due to their low frequency of occurrence.

However, it was possible to observe certain variability in the indiscriminate use of ignimbrite rhyolite, which was classified into different types, following physical characteristics such as color. In this regard, it can be said that the use of silicified ignimbrite rhyolite is quite similar to that in excavation No. 2, with the exception of the use in type 6, which does not present a high frequency. On the other hand, there is a preference for the use of type 1, which presents the highest frequency of occurrence, followed by type 6 (Table 10).

RAW MATERIAL EX. NO.3

RM	Pieces	%
IGNIMBRITE RHYOLITE	**1670**	**98,1**
TYPE 1	572	35,6
TYPE 2	177	11,0
TYPE 3	62	3,9
TYPE 4	41	2,6
TYPE 5	150	9,3
TYPE 6	401	25,0
TYPE 7	267	16,6
FLINT	**27**	**1,6**
A	14	51,9
SG	13	48,1
VOLCANIC	**4**	**0,2**
OBS	4	100,0
OTHER	**1**	**0,1**
SOR	1	100,0
TOTAL	1702	100,0

Table 10 Distribution of the lithic raw material on Ex. No.3

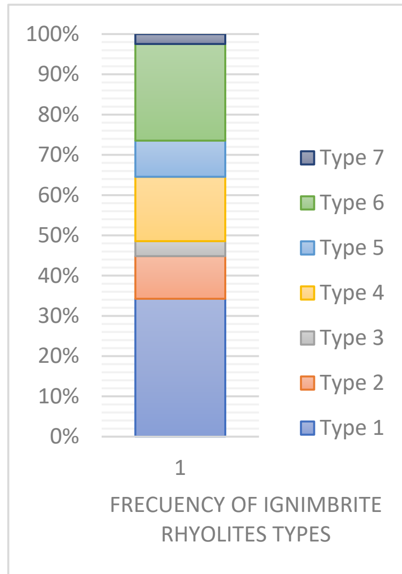


Figure 20 Distribution of the frequency of raw material on Ex. No. 3

1.1.1.1 Technological description

The lithic artifacts from excavation No. 3 are mainly represented by lithic products with 96.4% (1625 pieces) of the sample, while cores have a representation of 1.8% (30 pieces) and 1.8% (30 pieces) of elements with retouches were reported, among which some instruments and several fragments of bifacial instruments are highlighted. Among the latter, fragments of bifacial instruments, preforms and scrapers stand out. It should be noted that although these have the technological characteristics to be classified as instruments (due to the presence of retouch), during the traceological analysis it was not possible to determine their use in several of them (see section on traces of use in this chapter).

ARTEFACT	PIECES	%
Instrument	**30**	**1,8**
Blade	2	6,7
Flake	1	3,3
Fractured piece	27	90,0
Core	**30**	**1,8**
Flake	**1625**	**96,4**
Blade	17	1,0
Flake	387	23,8
Fractured piece	1221	75,1
Total	1685	100,0

Table 11 General distributions of the lithic assemblage Ex. No.3

A Layer 12

The lithic artifacts from excavation No. 2 are mainly represented by flakes with 96.4% (244 pieces) of the sample. On the other hand, cores have a representation of 3.2% (8 pieces) and only 0.4% (1 piece) of elements with retouches that were catalogued as possible instruments were reported. About the cores, 4 of them were catalogue as prismatic cores, 2 were catalogued as opportunistic ones, and the last 2 as amorphous cores with multidirectional negatives around.

ARTEFACT	PIECES	%
Instrument	**1**	**0,4**
Blade	1	100,0
Flake	0	0,0
Fractured piece	0	0,0
Core	**8**	**3,2**
Flake	**244**	**96,4**
Blade	2	0,8
Flake	37	15,2
Fractured piece	205	84,0
Total	253	**100,0**

Table 12 General distributions of the lithic assemblage Layer 2 – Ex. No.2

As mentioned, it is important to evaluate the state of conservation of the recovered elements to perform the technological analysis of the sample, since it allows us to identify the presence of the characteristics to be observed.

For layer 12 it was identified that most of the pieces were represented by distal fragments, followed by quite similar frequencies of pieces represented only by their mesial zone. In a second rank are complete pieces, and incomplete fragments (these fragments are those that were found mostly complete, but had some small fracture, which prevented their classification as complete pieces). It is important to note at this point that the analysis was carried out on all the recovered pieces, and the technological characteristics that could be obtained from each of the lithic products were recorded as long as the integrity and characteristics could be observed.

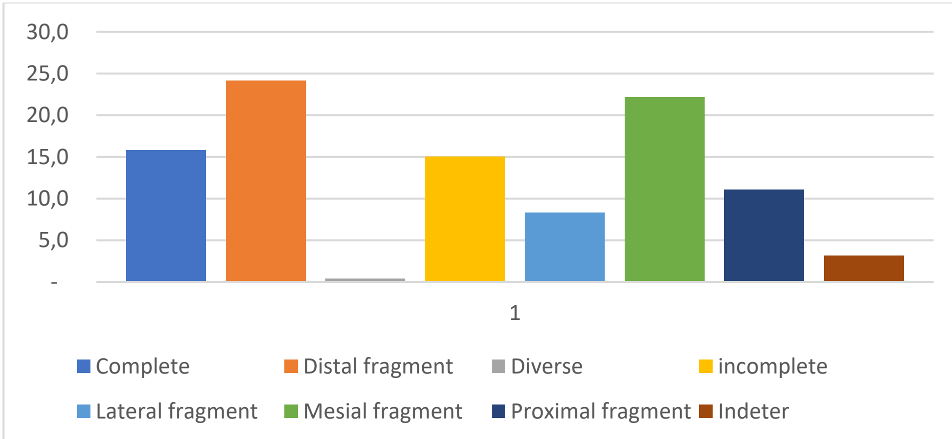


Figure 21 Integrity of the lithic products Layer 12 – Ex. No.3

A 95.3% (241 pieces) of the sample presented a total absence of cortical surfaces or cortex, which begins to locate the link of the reduction sequence. Of the remaining 4.7% of the sample, the most representative values are the pieces with a cortex in the mesial zone of the dorsum with 1.6% (4 pieces). The next categories are the pieces with a cortex in the lateral zone 1.2% (3 pieces), distal and proximal cortex with 0.8% (2 pieces each), and finally there is a single piece with the entire cortex on its dorsum.

Moreover, the butt could only be observed in 34.8% (88 pieces) of the recovered sample, the rest was fractured in such a way that it was impossible to identify the presence of this technological characteristic. Of the remaining pieces, the most representative butt is again the smooth one with a presence of 53.4% (47 pieces). In a similar frequency range is the rest of the butts, distributed from highest to lowest by the category of faceted butt 11.4% (10 pieces), dihedral 10.2% (9 pieces), pointed 9.1% (8 pieces), "oté" 8% (7 pieces), winged 6.8% (6 pieces) and finally a single specimen was recorded for the linear type.

The presence of bulb in the flakes was identified in 34.8% (165 pieces) of the sample from layer 12. As with the identification of butts, the study of bulbs was limited by the preservation of the pieces. Of the total number of bulbs recorded, 68.2% (60 pieces) were classified as intermediate or diffuse bulbs, followed by pronounced bulbs 30.7% (27 pieces) and only one non-pronounced bulb was recorded.

On the other hand, only 23.3% (59 pieces) of the sample were able to identify the type of extractions prior to each negative scar. The most representative were unipolar directions 44.1% (26 pieces), followed in a much lower frequency by crossed 23.7% (14 pieces), centripetal and convergent, both with 13.6% (8 pieces each) and finally a bipolar direction with a representation of 5.1% (3 pieces).

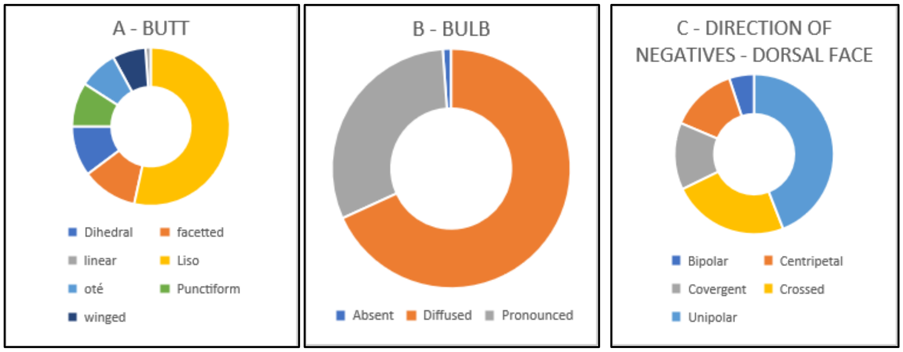


Figure 22 Graphics of the technological characteristics on the layer 12 – Ex. No. 3: A – Butt; B – Bulb; C – Direction of the negatives – Dorsal face.

Regarding unintentional accidents and intentional modifications, a total of 2.7% (7 pieces) presented some type of technological accident. The most representative type was involuntary fracture during knapping with 0.7% (2 pieces), followed by "siret" type accidents with 1.5% (4 pieces) and finally a single specimen was recorded with the presence of "parasite flake". It was identified that thermal modification is present in the sample, however, its representation is somewhat scarce with a total of 1.5% (4 pieces) with respect to the sample of pit No. 2.

A particularity of layer 12 is that the initial geoarchaeological studies indicated that the upper part of it was washed away by a flood of the Mayales River. This means that the representation of this layer, although high in frequencies, is not accurate to identify trends. However, it is worth mentioning that this layer shows a certain homogeneity in its composition, since most of its elements belong to a single lithic reduction sequence associated with the production of bifacial tools presented on the lower layers.

B Layer 14

Layer 14 is the stratigraphic level with the most lithic archaeological material. During the excavation, a total of 898 pieces were recovered, distributed in different categories of analysis. On the other hand, this layer presented a high frequency of retouched elements, most of which belonged to fragments of bifacial instruments.

The lithic artifacts of layer 14 are mainly represented by flakes 95.5% (858 pieces), followed by pieces that presented retouches and were classified as tools or part of one with 2.3% (21 pieces), and finally, the sample was represented by 2.1% (19 pieces) corresponding to cores of various types. About the cores it can be says that none of them were catalogue as prismatic cores, and most of them were categorized as amorphous type.

ARTEFACT	PIECES	%
Instrument	**21**	**2,3**
Blade	1	4,8
Flake	0	0,0
Fractured piece	20	95,2
Core	**19**	**2,1**
Flake	**858**	**95,5**
Blade	11	1,3
Flake	208	24,2
Fractured piece	639	74,5
Total	898	**100,0**

Table 13 General distributions of the lithic assemblage Layer 14 – Ex. No.3

The integrity of the flakes from layer 14 was guided by the high frequency of fragments of distal pieces 25.7% (231 pieces) and complete pieces 24.6 (221 pieces), which together account for more than 50% of the sample. In a second frequency range, the categories for incomplete fragments 14.9% (134 pieces), proximal fragments 14.8 (133 pieces) and mesial fragments 12.4% (111 pieces) are identified. In a third level are located the categories that group the pieces of diverse fragments 4.6% (41 pieces), indeterminate pieces 2.2% (20 pieces) and finally lateral pieces 0.8% (7 pieces).

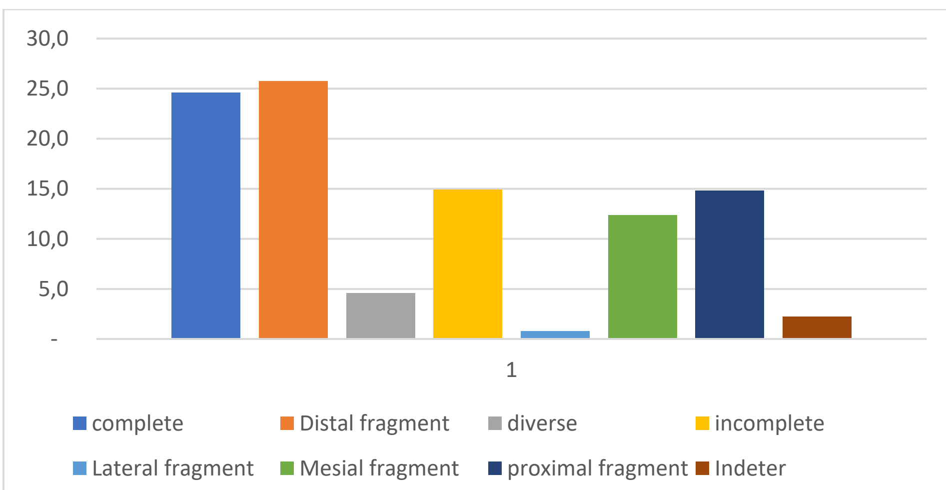


Figure 23 Integrity of the lithic products Layer 14 – Ex. No.3

A 94.4% (848 pieces) of the sample presented a total absence of cortical surfaces or cortex, which begins to locate the production link of the collection studied. Of the remaining 6.6% of the sample, the most representative values are the pieces with a cortex on one of its sides, 2.1% (19 pieces). Next and sharing a similar representation are the rest of the categories: diverse 1.1% (10 pieces), distal 0.9% (8 pieces), proximal and total, sharing the same frequencies of 0.6% (5 pieces) and finally a single piece with all its dorsal face with cortex.

The identification of the but in the flakes was only possible in pieces that, due to their integrity, maintained their percussion platform intact. This characteristic was possible to identify in more than half of the sample with a total of 53.9% (484 pieces), the rest were fractured in such a way that it was impossible to identify the presence of this technological characteristic. Of the remaining pieces, the most representative butt is again the smooth one with a presence of 53.9% (291 pieces). In a similar frequency range are the faceted butts, with 14.9% (72 pieces) and linear 9.1% (44 pieces). The rest of the butts are distributed in a range of less than 6%: pointed 5.8% (28 pieces), dihedral 5.4% (26 pieces), "oté" type 2.5% (12 pieces), winged 1.4% (7 pieces), and finally with a presence of 0.8% (4 pieces) is the cortical. In this layer it is evident the high presence of butts suitable for a delicate knapping for a complex manufacture, such as a bifacial or a laminar debitage type (Andrefsky Jr, 2008; Arzarello et al., 2011; Inizan et al., 1999).

Of the total number of bulbs recorded, 60.5% (293 pieces) were classified as diffuse bulbs, followed by 20.9% (101) classified as pronounced bulbs and 18.6% (90 pieces) classified as absent bulbs.

Regarding the identification of the flake negatives of the dorsal face of the lithic products (flakes/blades), this was identified in 47.9% (431 pieces) of the total sample of the layer. Two frequency distribution ranges were recorded from this sample. The first range was composed of unipolar type directions 36.7% (158 pieces) and crossed 30.6% (132 pieces). The second range contained the convergent 14.4% (62 pieces) and centripetal 11.8% (51 pieces). Finally, in the last range, bipolar type negatives were identified with a representation of 6.5% (28 pieces) of the sample.

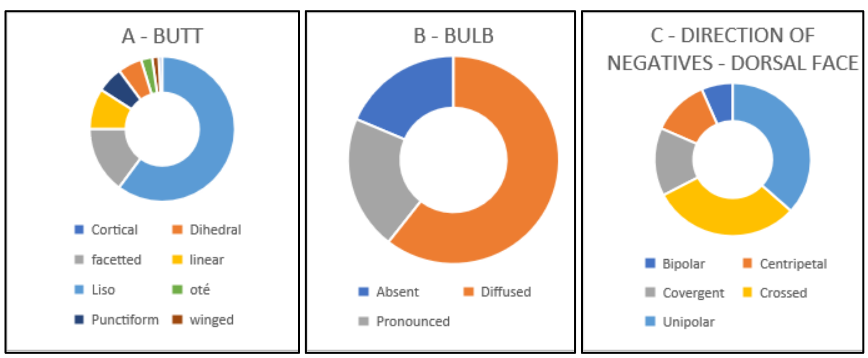


Figure 24 Graphics of the technological characteristics on the layer 12 – Ex. No. 3: A – Butt; B – Bulb; C – Direction of the negatives – Dorsal face.

Regarding unintentional accidents and intentional modifications, a total of 67.5% (606 pieces) presented some type of technological accident. This is the highest frequency of all the pits and layers studied and is very much in accordance with the rest of the lithic evidence recovered, especially with the high presence of fractured retouched bifacial elements. The most representative type was unintentional fracture during knapping with 77.7% (227 pieces), followed by "hinge termination" type accidents with 16% (47 pieces). The third frequency of accidents identified was the "siret" type fracture with a representation of 3.4% (10 pieces). Finally, a total of 1.3% (4 pieces) of "parasite flake" were recorded.

As mentioned at the beginning, layer 14 is the layer with the highest archaeological frequency in all the cortexes of the Roberto Amador site. In addition to this, it is also the layer with the highest number of retouched elements with a total of 21 pieces, of which more than half represented bifacial instruments in two main states, preforms and fractures of bifacial pieces in a state close to completion.

INSTRUMENT	PIECES	%
INDETERMINATE	3	14,3
BIFACIAL INSTRUMENT	12	57,1
DENTICULATE (?)	1	4,8
SCRAPER	5	23,8
TOTAL	21	100,0

Table 14 Frequency of the retouched artefacts in Layer 14 – Ex. No.3

C Layer 16

The lithic artifacts of layer 16 are composed of a total of 404 pieces distributed in 96.6% (391 pieces) of flakes, 1.7% (7 pieces) of cores and 1.5% (6 pieces) of artifacts or retouched pieces. About the cores it can be say that this is the only layer that present a discoidal core, meanwhile the rest of it were catalogued as amorphous cores with multidirectional negatives.

ARTEFACT	PIECES	%
Instrument	**6**	**1,5**
Blade	1	16,7
Flake	0	0,0
Fractured piece	5	83,3
Core	**7**	**1,7**
Flake	**391**	**96,8**
Blade	4	1,0
Flake	104	26,6
Fractured piece	283	72,4
Total	404	**100,0**

Table 15 General distributions of the lithic assemblage Layer 16 – Ex. No.

Regarding the integrity of the lithic products from layer 16, we can say that, unlike the rest of the layers, the highest frequency portion is found with a complete integrity of 27% (109 pieces). In a similar distribution are the distal fragments, which are represented by 25.2% (102 pieces). In a second frequency range are mesial 15.6% (63 pieces), proximal 13.6% (55 pieces) and incomplete 12.9% (52 pieces). In the lower frequency range are located the pieces with diverse integrity 3.2% (13 pieces), indeterminate 1.7% (7 pieces) and finally, the lateral pieces with a representation of 0.7% (3 pieces).

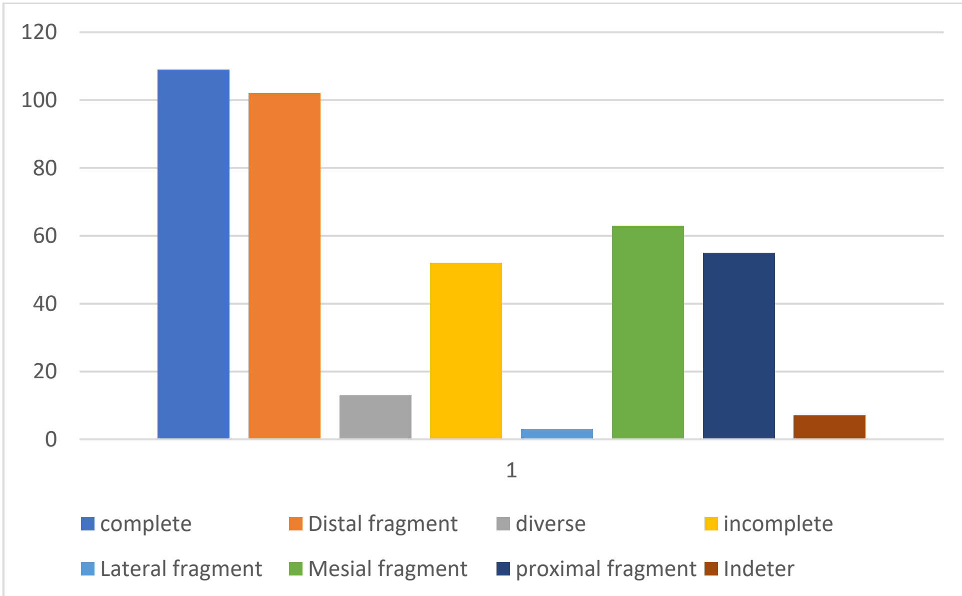


Figure 25 Integrity of the lithic products Layer 16 – Ex. No.3

Like the rest of the stratigraphic layers, the absence of cortex was mostly predominant in layer 16. The absence of cortex in the lithic products was reflected in 94.6% (382 pieces) of the total sample. As has been suggested for the rest of the layers, this characteristic suggests that the reduction sequence was located on a stage where the previously suitable raw material is being modified. Next and in a similar frequency range, we have the presence of cortex in lateral areas in 1.7% (7 pieces) of the sample; distal areas, diverse and a total presence of cortex in the dorsal surface, share the same frequency of 1% (4 pieces).

On the other hand, the type of butt was recorded in 53.2% (215 pieces) of the sample recovered. Of this sample, the most representative butt was the smooth heel with a representation of more than half with 55.3% (119 pieces). In a second range of frequencies are the faceted butts 12.6% (27 pieces) and linear 10.2% (22 pieces). Next are the dihedral butts 7.4% (16 pieces), "oté" and punctiform share 6.5% (14 pieces) and finally there is a representation of 1.4% of cortical butt.

Regarding the bulb, it could be identified in 53.2% of the total sample. Of all the bulbs recorded, 50.2% (108 pieces) showed a diffuse bulb pronunciation, 27.4% (59 pieces) showed a pronounced bulb and finally, 22.3% (48 pieces) showed a total absence of bulb.

The identification of the direction of the negatives on the dorsal face of the flakes was possible in 45.3% (183 pieces) of the total sample of the layer. Of this total, and as for the upper layer (14), two frequency distribution ranges were identified. The first was composed of unipolar directions 15.5% (67 pieces) and crossed 13.7% (59 pieces). The second was made up of convergent type directions 6% (26 pieces), bipolar 3.9% (17 pieces) and centripetal 3.2% (14 pieces).

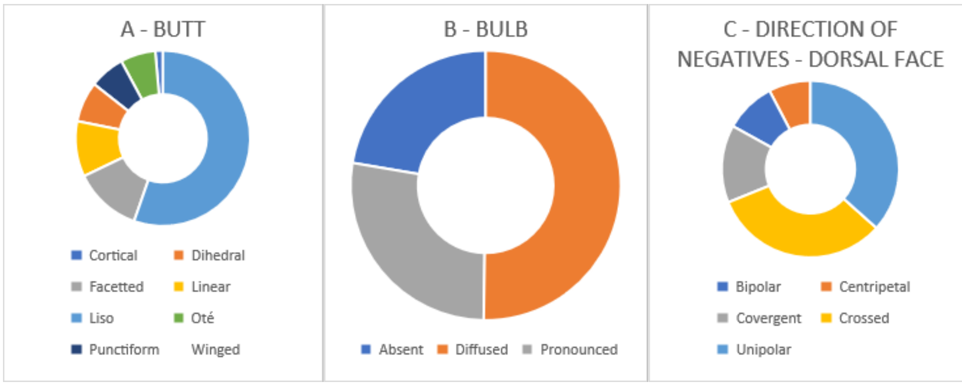


Figure 26 Graphics of the technological characteristics on the layer 12 – Ex. No. 3: A – Butt; B – Bulb; C – Direction of the negatives – Dorsal face.

Regarding unintentional accidents and intentional modifications, it can be said that more than half of the pieces 54.2% (219 pieces) presented some type of technological accident. This is the second highest frequency of all the pits and layers studied. The most representative type was unintentional fracture during knapping with 38.3% (155 pieces), followed by "hinge termination" type accidents with 5.7% (23 pieces). The third frequency of accidents identified was the "siret" and "parasite flake" type fracture with a representation of 0.5% (2 pieces) each.

Layer 16 presented a total of 5 pieces with evident retouch on one or more of their edges. In fact, 4 pieces were catalogued as fragments of bifacial pieces in production and one as a scraper.

INSTRUMENT	PIECES	%
BIFACIAL INSTRUMENT	4	80,0
SCRAPER	1	20,0
TOTAL	5	100,0

Table 16 Frequency of the retouched artefacts in Layer 16 – Ex. No.3

Finally, it is made clear that there are two layers that overlie those previously described and that presented lithic material (layers 18 and 19). However, due to the low frequency of these, they will not be described in this chapter, but general trends will be generated and discussed. The frequencies can be seen in the appendix of data base, which presents the general database of the studied layers.

1.1.1.2 Technological Trends

In general terms, the technological trends of the excavation No. 3 were very similar to the one presented on the excavation No. 2, but with a higher frequency of lithic products, and a wider representation on the different stages of the reduction sequence of blade production and shaping bifacial instruments.

According to the bibliographic review, most of the lithic assemblage from excavation no. 3 was manufactured from local raw materials (see the Materials and Methods chapter for the raw material discussion). Although the technological analysis did not present solid evidence on the type of nodules used, it did show a slight tendency to use secondary raw material sources (Terradas, 2001). In other words, the nodules exploited were cobbles (and probably boulders) and were obtained from the surrounding water flows[15]. This behavior was repeated for the three archaeological layers studied 12, 14 and 16.

According to several lines of evidence such as the morphology of the flakes, the experimentation developed in the research and the archaeological literature (Andrefsky Jr, 2008; Arzarello et al., 2011; Inizan et al., 1999), the knapping technique used was mainly the same as the one used on the excavation No. 2, which was direct percussion with soft/organic hammer, and in a lesser way, direct percussion with hard hammer and by pressure for some few retouched. These last products attest one of the last stages of the lithic reduction sequences identified for bifacial shaping. This trend was also identified for the three stratigraphical layers.

Within the whole assemblage, two different lithic reduction sequences were identified and both present in all the layers. One sequence is focus on the blade production and the other to achieve shaping elements, bifacial tools.

- As well as excavation No. 2, the lithic reduction sequence related to blade production in the excavation No. 3 is not complete due to the absence of some adequation stages at the site. The absence of core preparation flakes and the presence of technical preparation flakes (ridge flakes), together with the low frequency of complete flakes attest to two scenarios. First, laminar cores were previously prepared and taken to the area of the excavation No. 3 in order to be exploited by the blade production. Second, the final products of this reduction sequence (blades) were transported to area of Roberto Amador site for it use[16]. It means that the area of the excavation No. 3 was a space focus on the manufacturing of laminar products which were taken away for it use. This is a tendence of the 3 layers studied, among all present a very few complete blades products and an absence or very few presences of cores.

  Finally, its remarkable that the only layer that present laminar cores was the 12 with a total of 4. In a contrary way, this layer only presents a few complete blade products (3 pieces). As in the case of excavation No. 2, the recovered cores show a classic morphology with transverse and longitudinal convexity and measurements that allow it to be catalogued as still productive (see Figure 27). There is no technical explanation for the abandonment of this cores. Finally, it should be noted that the tendency of the blade production is quite similar among the 3 different layers (Figure 28).

[15] It should be recalled that according to the geological literature, it is possible to identify the silicified ignimbrites rhyolites in the form of river pebbles.
[16] The traceological analysis was unable to determine any use wear in any product (complete or incomplete) related to the blade reduction sequence.

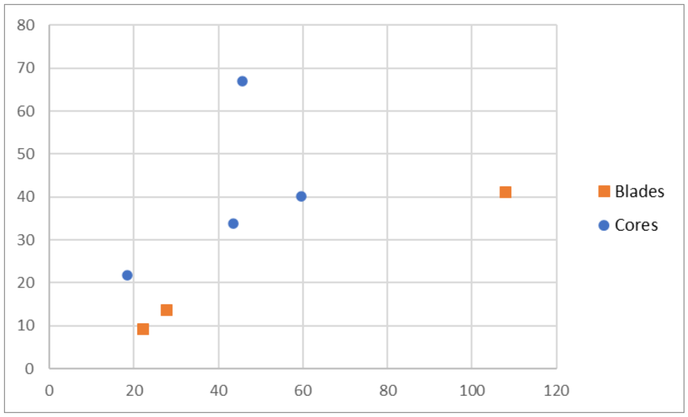


Figure 27 Relation between the measures of the complete blades and the only core found in the Layer 12-Ex no. 3.

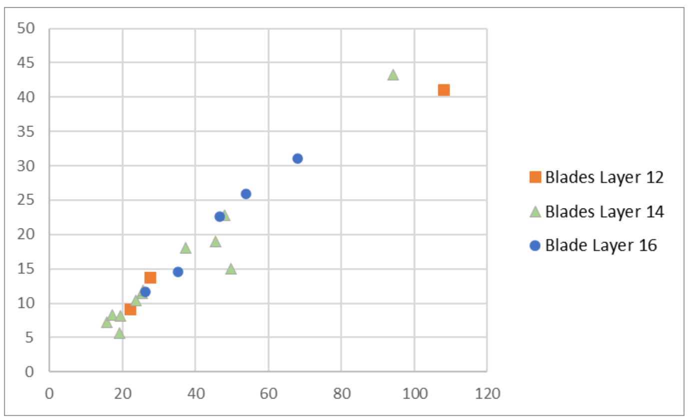


Figure 28 Relation between the measures of the complete blades from all the stratigraphic layers (12, 14 and 16) of the Ex no 3.

- The shaping, unlike the laminar reduction sequence, presents lithic products belonging to different stages of the flintknapping operations for the manufacture of bifacial tools. Also, and this is an important difference with excavation 2, preforms and fragments of final products (bifacial tools) are present in the assemblage with the flakes of the different stages of bifacial shaping. Regarding the preforms (which are only present in the layer 14 with 2 samples), it can be understood that the blanks of the bifacial tools were big flakes (see Photo 7) technical characteristics of this preforms suggest an exploitation with hard hammerstone over cobbles of silicified ignimbrite rhyolite for the creation of these preforms for bifacial shaping.

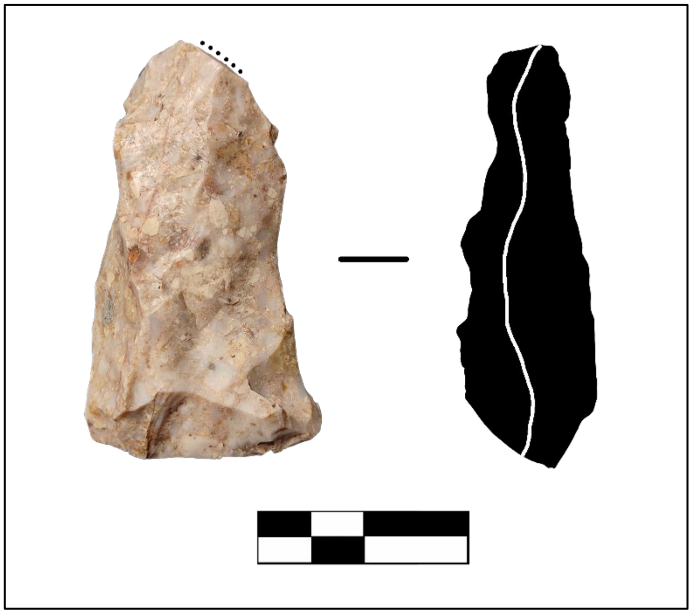


Photo 7 Ex 3 – Layer 14 – Bag 125 – Preform. The dots show the striking platform of the Flake/Blank. This preforms have already created the peripherical striking platform, but during the creation of the bifacial equilibrium one face became flatter than the other, reason why it was discarded.

Regarding the shaping flakes (*Façonnage*), they attest all the 3 different stages of the manufacturing process of a bifacial artefact.

Initially, it is possible to identify, in a low frequency, flakes whose objective was to create a peripheral striking platform. These products were extracted by direct percussion with a hard hammer, although some pieces were recorded that suggest the use of a soft percutor for this same task. These products are characterized by presenting a clean impact point on a butt usually characterized as plain and by having a normally prominent bulb, catalogued as pronounced. These flakes tend to have a higher metric ratio than the rest of the flakes, presenting wide thicknesses and elongated pieces. Another characteristic of these products is their lack of a curved longitudinal profile.

The second stage, generation of a bifacial equilibrium plane, is represented by flakes extracted entirely by direct percussion with an organic hammer. These flakes are characterized by having prepared and thin butts, with bulbs that are not prominent and have been characterized mainly as diffuse. The width and length measurements of these products tend to be smaller and use to present convexity in the longitudinal profile due to the elasticity given by the knapping with organic hammer. Another characteristic of these products is that the negatives on their dorsal face tend to be convergent and unipolar, which suggests a knapping focused on the roughing and thinning of the piece.

The third and last stage in the manufacture of a biface is the generation of the bilateral equilibrium plane and is exemplified by products that have been extracted in their entirety by direct percussion technique with an organic percutor. Likewise, these products are characterized by presenting a prepared heel, as well as a very diffuse or absent bulb. These products, due to their purpose of giving the artifact its final morphology, present small sizes that are characterized by a low thickness.

Some flakes that were recover were catalogued as products generated by retouching. These pieces tend to present a similarly small size, but with the difference of presenting a very sharp striking platform angle, as well as small negatives produced in the proximal area of the dorsal face of the piece. The presence of these pieces is very scarce, so it can be interpreted that the retouching or re-sharpening stage did not take place in the area of excavation No. 2, since the frequency of occurrence of these pieces is minimal in both layers.

The presence of a part of the final product of the bifacial shaping (fragments of bifacial tools), is quite important evidence that allow us to understand the operative scheme of the production site. A total of 14 fragments of bifacial instruments where recover, 10 for layer 14, 1 for layer 12 and 3 for layer 16. All of these pieces are fragmented in different ways (distal fragment, mesial fragment, proximal fragment). Only one present a reshaping for create a bifacial with a trapezoidal shape (see Photo 8).

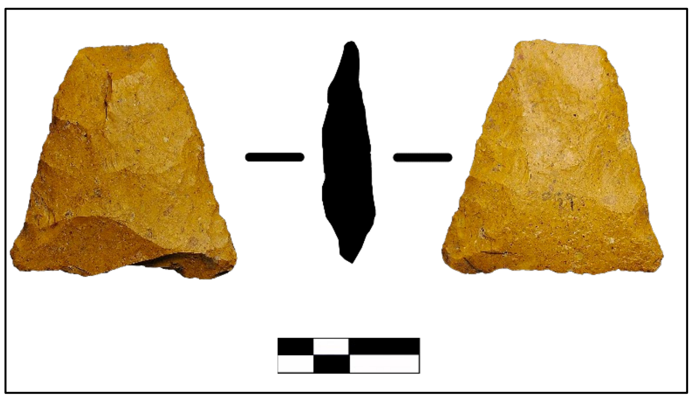


Photo 8 Ex 3 – Layer 14 – Bag 171.1. Broken bifacial tool and reshaping for make a new bifacial tool with a trapezoidal shape. The piece was discarded and don't show any use wear during the traceology analysis.

5.2 Statistical results

As mentioned in the methodological section, the general investigation only considered the lithic materials recovered in excavation sections 2 and 3. Although all the elements present in these sections were technologically analyzed, a representative sample was defined for the statistical analyses that sought to study the technological variability, which was established following different parameters.

Since the nature of this research seeks to make an initial approach to the composition of a lithic assemblage from the Robeto Amador site, a series of variables were established that the elements to be studied had to comply with to be part of the statistical sample. First, it was decided to use only the elements of the most representative layers of the two archaeological excavations, which were layers 2, 15 (ex. 2), 12, 14 and 16 (ex. 3).

Once the layers of major interest for the statistical analysis had been identified, the sample was selected. This selection was guided mainly by the complete integrity of the pieces, leaving aside any elements that were incomplete or fractured. The reason for this was the possibility of performing metric analysis on these pieces. Likewise, the instruments made on flakes were left aside due to two reasons: they have a low frequency of occurrence (n=9) and most of the pieces are fracture.

At the end and after the sample purification for statistical analysis, 427 flakes (complete), 42 cores, and 18 bifacial artifacts (preforms, fractured pieces, complete pieces). A total of 487 elements were obtained from a set of 2059 pieces, distributed in 5 layers and two archaeological excavations. This sample is equivalent to 23.6% of the assemblage.

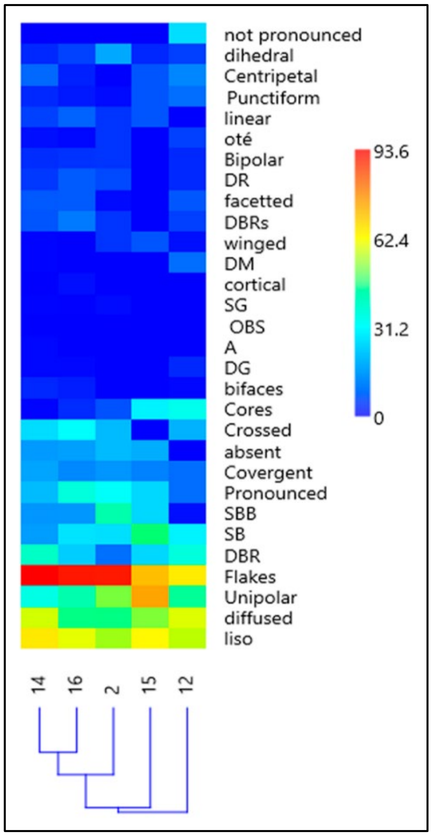
Once the sample was selected, the most representative technological features were selected for the statistical analysis. Table 17 shows the database used for the statistical analysis carried out in this research. This frequency table discriminates the lithic pieces recovered by layers/excavations and presents the frequency of occurrence of the different technological characteristics.

	ARTEFACTS				RAW MATERIAL								BUTT									DIRECTION OF THE NEGATIVES					BULB					
LAYER	**Flakes**	**Cores**	**Bifacial art.**	**A**	**DBR**	**DBRS**	**DG**	**DM**	**DR**	**OBS**	**SB**	**SBB**	**SG**	**Cortical**	**Dihedral**	**Facetted**	**Linear**	**Plain**	**Oté**	**Punctiform**	**Winged**	**Bipolar**	**Centripetal**	**Convergent**	**Crossed**	**Unipolar**	**Absent**	**Diffused**	**Not pronounced**	**Pronounced**	**TOTAL**	**%**
2	44	5	0	0	6	3	0	0	4	0	12	18	1	0	9	1	3	24	3	1	3	3	0	8	10	23	10	20	0	14	**44**	10,30
15	19	8	0	0	5	0	0	0	0	0	9	5	0	0	1	0	2	12	0	2	2	0	2	3	0	14	4	10	0	5	**19**	4,45
12	37	19	1	0	13	3	2	5	2	0	11	1	0	0	3	4	0	21	3	5	1	2	6	5	8	16	0	22	10	5	**37**	8,67
14	219	3	12	4	83	23	4	3	16	1	42	40	3	1	12	24	18	143	6	12	3	13	28	44	59	75	41	128	0	50	**219**	51,29
16	108	7	5	0	27	16	2	0	12	0	30	20	1	3	9	12	13	65	2	4	0	7	5	18	34	44	21	49	0	38	**108**	25,29
TOTAL	**427**	**42**	**18**	**4**	**134**	**45**	**8**	**8**	**34**	**1**	**104**	**84**	**5**	**4**	**34**	**41**	**36**	**265**	**14**	**24**	**9**	**25**	**41**	**78**	**111**	**172**	**76**	**229**	**10**	**112**	**427**	100
%	87,7	8,6	3,7	0,9	31,4	10,5	1,9	1,9	8,0	0,2	24,4	19,7	1,2	0,9	8,0	9,6	8,4	62,1	3,3	5,6	2,1	5,9	9,6	18,3	26,0	40,3	17,8	53,6	2,3	26,2		

Table 17 Frequency of the lithic pieces and the technological features.

5.2.1 Morphological and technological variability both at the layer and slice level

Figure 29 Cluster of two-way grouping the layers with all the variables.



To begin the exploration of technological variability, a cluster was constructed in which all the technological features were related, as well as the presence of cores and bifacial artifacts by layers. For this purpose, a two-way cluster analysis (Euclidean) was run (see Figure 29). This cluster shows that there are certain variables that are more prone and important for grouping layers. It is interesting to initially observe this division since this analysis suggests a grouping in which layer 12 is the most distant of all but has a certain spatial similarity with layer 15. The opposite case occurs with layers 14 and 16, which are grouped together and closely located to layer 2. Another aspect to highlight is the identification of variables that have an important incidence, and which do not for grouping. For example, we see that the presence of flakes (because is the higher value in frequency) is one of the strongest variables, together with plain butts, diffuse bulb, and unipolar negatives. The opposite case occurs with variables such as some raw materials due to their low representativeness (DG, A, SG, OBS-obsidian), or cortical type butts.

Morphometric analysis of the specimens yielded more concrete data than descriptive statistics. It is important to mention that the management of the morphometric data was handled with the median and the inter-quartile range was used as a measure of central dispersion (Table 18). This is because most of the measurements present in bifacial artifacts, cores and flakes presented a very wide dispersion, as well as a sufficiently important presence of outsiders (see Figure 30). Saying that, the sample can be morphometrically divided into two groups, the first bifacial artifacts and the second flakes and cores (see Figure 30). The first are elements that in their totality (although some are incomplete) presented large sizes greater than 60 mm. Although certain flakes and cores reached similar large sizes, these were exceptions and according to the boxplot, they should be catalogued as outsiders. On the other hand, it is possible to observe an interesting relationship between the distribution of the metric measurements of these two elements separately and together.

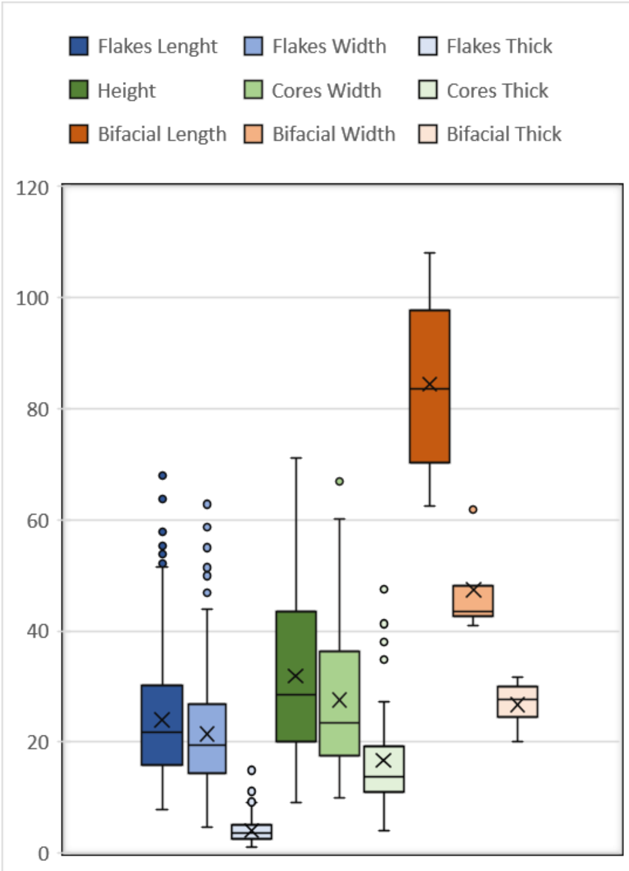


Figure 30 Box plot of the Length, Width, and thickness of the different lithic artefacts.

ARTEFACT	MEASURE	MEDIAN	IQR
FLAKE	L	21,4	13,675
	W	19,75	19,075
BLADE	L	27,7	26
	W	11,9	9,7
CORE	L	28,55	23,975
	W	23,35	19,075
BIFACIAL	L	83,565	39,6575
	W	43,45	15,675

Table 18 Metric of the lithic artifacts. L=length, W=width.

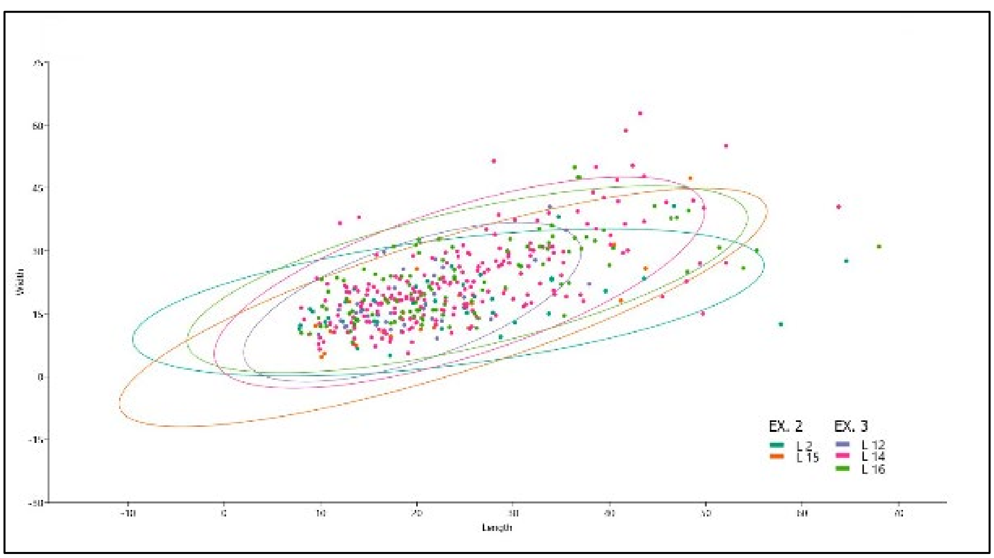


Figure 31 Dot plot combining the distribution of the metrics of lithic flakes per layer.

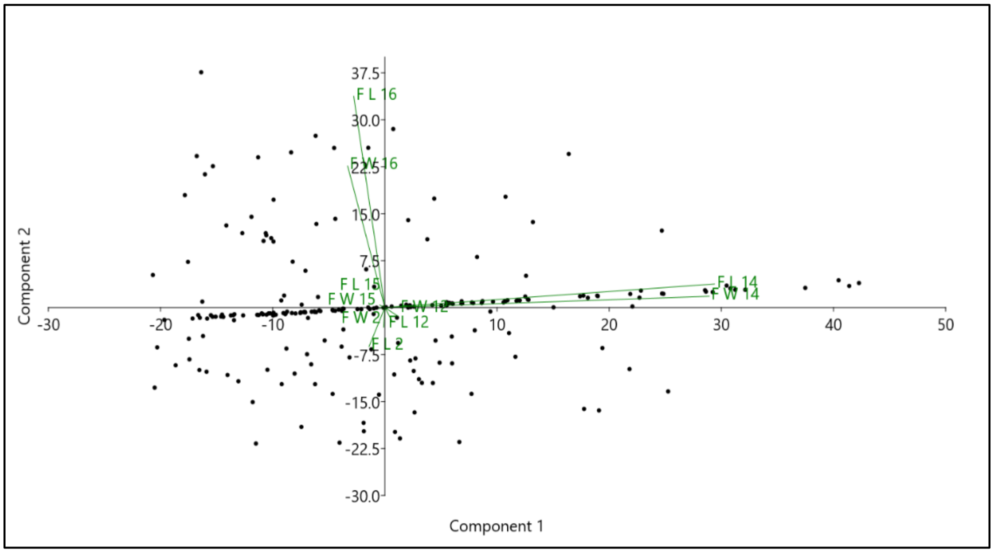


Figure 32 PCA of the metrics (L and W) of the lithic products per layer

In Figure 31 it is possible to observe the spatial distribution of the length and width measurements of each of the lithic products present in the statistical sample. It can be seen how each layer is represented by a color. It is worth noting that most of the flakes in each layer tends to be grouped in the same measurements. It is also worth noting that the 95% ellipses all have the same inclination and are almost all located on the same trend (except for layer 12). The dispersion analysis is very telling since the morphometric behavior of the lithic products tends to behave in the same way in the 5 layers, which suggests a similar use and exploitation of the raw material for different moments and spaces of RA site. To support the inferences from the dot plot, a Principal Component Analysis (PCA) was performed on the metric frequencies (according to the Shapiro-Wilk normality test the metric data are normal, so a PCA can be run, and more accurate results can be expected) (see Figure 32). This PCA reached more than 80% variance in its 3rd PC. It can be seen in the graph where the first two PCs are plotted how layers 2, 12 and 15 are related in terms of lithic products metrics, while for layers 16 and especially 12, the PCA suggests an important difference. The difference for layer 14 may lie in the fact that it is over-represented in terms of lithic products with frequency of 52% of the sample (see Table 17).

On the other hand, cores showed a distribution of sizes that tended to be similar among the different layers (see Figure 33). Although the trend of core size varies in the 5 layers, they tend to behave in a similar way. Unlike the flakes, the values of the cores presented non-normal values, so a logarithmic transformation was performed to normalize the data[17]. In Figure 35 it is possible to observe that the distribution of the cores is much more disparate than for the flakes. However, the distribution trend continues to be repeated: there is a spatial relationship in the PCA for the cores

[17] It is worth mentioning that this transformation failed to normalize the data, but according to(Drennan & González, 2019), it is better to work with such transformed data (even if they have not been normalized), than with untransformed data.

from layers 2 and 12, which tend to be grouped in the center, while the cores from layers 14 and 16 continue to present a significant distance, as well as the cores from layer 15.

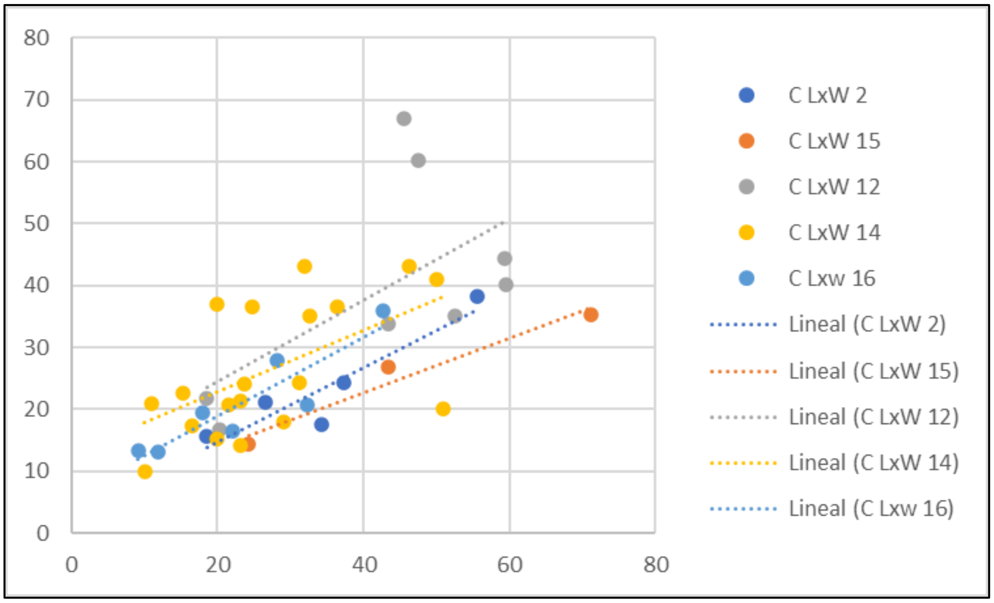


Figure 33 Dot plot combining the distribution of the metrics of cores per layer.

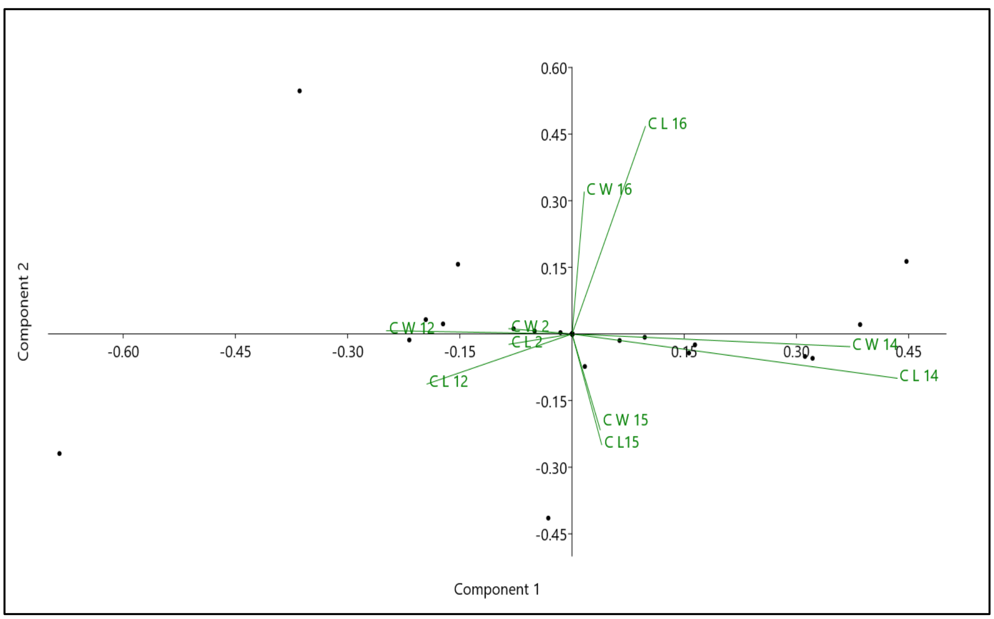


Figure 34 PCA of the metrics (L and W) of the cores per layer

If both variables are related, it can be observed that the sizes of the flakes and cores correspond in their minimum and maximum values, which indicates the development of a lithic production sequence of total use of the cores in the area (Figure 35).

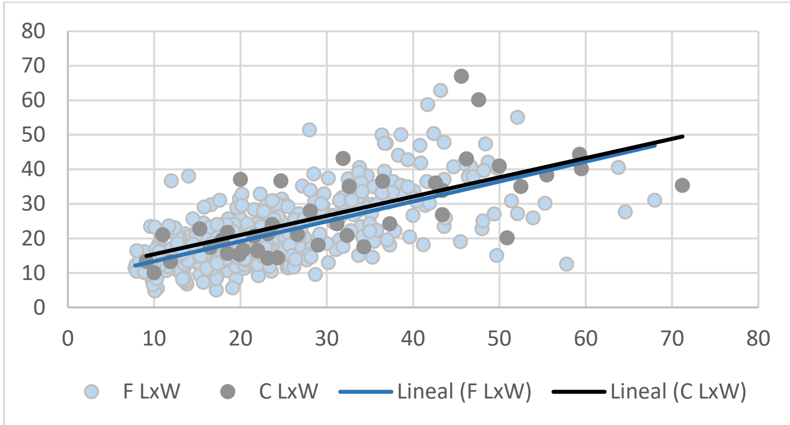


Figure 35 Dot plot combining the distribution of the metrics of cores and lithic products.

Finally, and as an exploration, a principal component analysis is performed to explore the relationship between the measurements and the types of artifacts recovered in the field (Figure 36). Although not very revealing at first sight, this graph offers the interpretation of how morphometric characteristics of the lithic materials in the terrace where the RA site is located can be outlined. This PCA obtained more than 95% of variance in its 2nd PC.

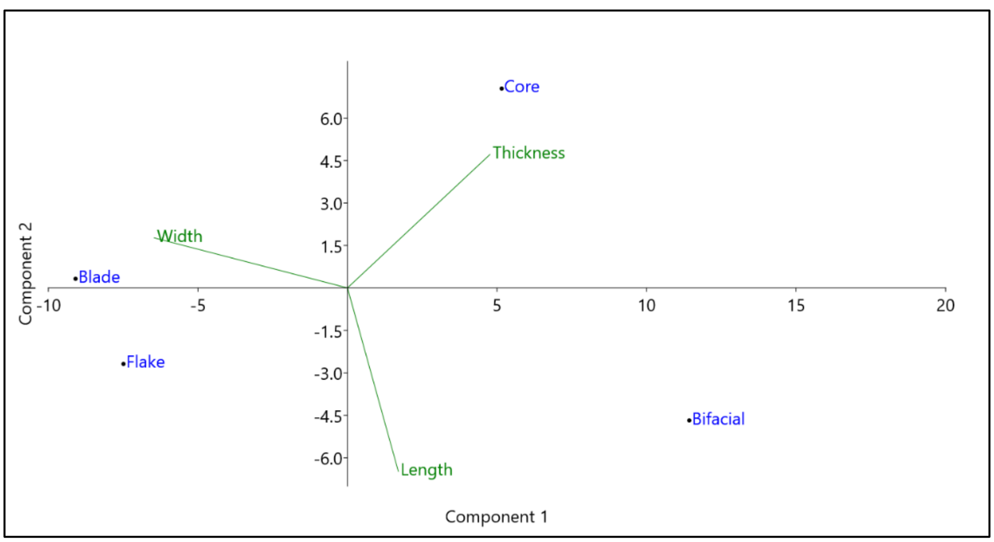


Figure 36 PCA of the lithic artefacts and the Metrics.

On the other hand, identifying and characterizing the different forms present in the lithic pieces is usually of great relevance for the interpretation of archaeological contexts. Because the lithic assemblage of the RA site presents a small portion of lithic blades (6.3%) among the lithic products (identified during the technological analysis), a shape index on the flakes/blades was used to explore this component. It is a consensus among archaeologists that a debitage can be categorized as a blade only if its length is twice or more its own width (Arzarello et al., 2011; Inizan et al., 1999). This is why, to define the shape index of each lithic debitage, the length of the debitage was divided by its width. Depending on the result, the shape of the debitage can be inferred: values below 2 are flakes and values above 2 are blades (*sensu stricto*) (Arzarello et al., 2011; Inizan et al., 1999). This index allowed us to identify and isolate blades from flakes to construct a frequency table for laminar technological features (see Table 19) and thus analyze each item separately.

Layers	A	DBR	DBRs	DG	DM	DR	OBS	SB	SBB	SG	Cortical	Dihedral	Facetted	Linear	Plain	Oté	Punctiform	Winged	Bipolar	Centripetal	Covergent	Crossed	Unipolar	Absent	Diffused	Not pronounced	Pronounced
2	0	1	0	0	0	0	0	1	5	0	0	0	0	2	4	0	0	1	2	0	0	0	5	1	5	0	1
12	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2	0	0	2	0
14	0	5	0	2	0	1	0	2	1	0	0	1	2	0	5	0	2	1	1	2	1	2	5	5	6	0	0
15	0	1	0	0	0	0	0	2	0	0	0	0	0	1	1	0	1	0	0	0	0	0	3	1	2	0	0
16	0	1	1	0	0	1	0	0	1	0	0	2	0	0	2	0	0	0	0	0	1	0	3	1	3	0	0

Table 19. Blades and the frequency of technological features per layer.

To explore the relationship between the technological features of the blades, a Kendall[18] correlation analysis was performed, which can be seen in Figure 37. This graph is quite interesting because it relates the technological features that, according to different lithic studies, are present in the blades (Burton, 1980). For example, the tendency to present a positive correlation with an absent and diffuse bulb (the two recurrent categories in the production of blades), or the correlation between butts that require a previous preparation for the extraction of blades and certain raw materials (dihedral, faceted, punctiform) (Burton, 1980; Inizan et al., 1999). However, it is important to emphasize that this initial observation has been made with a representative sample too low (n=27). Even so, this analysis allows us to begin to outline the technological characteristics of the blades at the RA site for future research.

Regarding flakes, these represent 93.6% (n=400) of the sample and present a wide variety in shapes, as well as in their individual characteristics. To explore the relationships between the technological features and flakes, the same path was followed as for the blades.

Another objective of this study is to explore what type of relationship exists between the archaeological layers and the technological features of the lithic elements in the RA site. For this purpose, a principal component analysis will be carried out in which the layers are related to the frequency of each of the technological features studied in the flakes (Figure 38). This analysis was performed on the sample transformed in percentage for two reasons. First, this transformation sought to reduce the variability of the frequencies in the variables and thus improve the normality of the data. Second, and no less important, all the statistical analyses applied in this work have been performed on the variables in percentages except those related to the metrics. To using the same trend, we will continue using variables transformed into percentages.

[18] According to Shapiro's normality test, the data are not parametric.

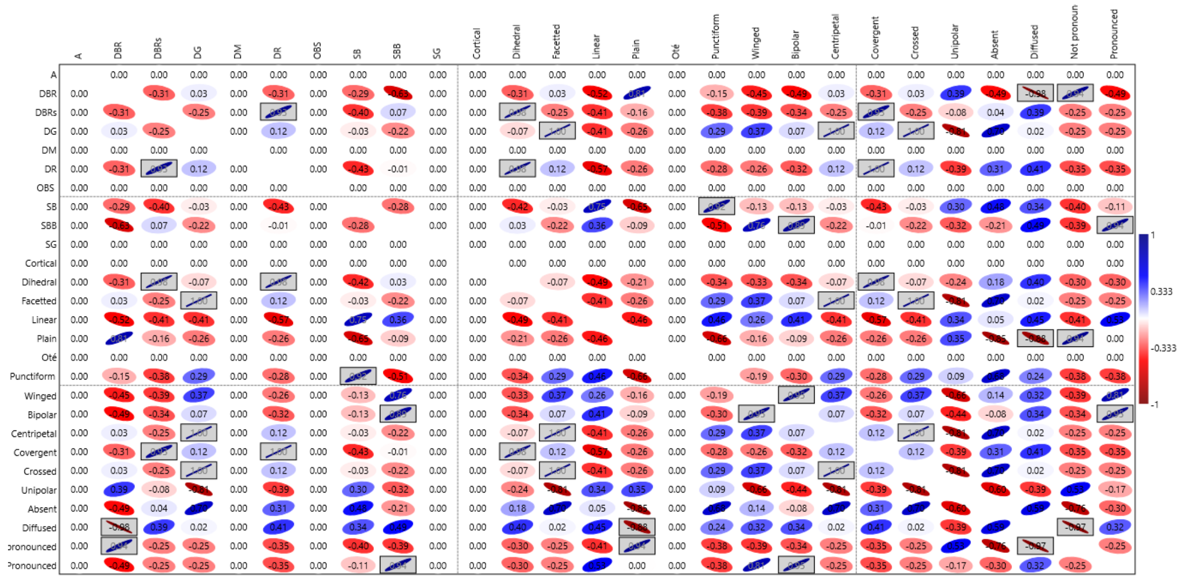


Figure 37 Kendall´s correlation for the technological features and blades.

The result of the PCA managed to group more than 80% of variance in the second component and more than 95% in the third component. The loadings of each component can be seen in Table 20. To better filter the information of this analysis, all values below a variance of 0.1 have been eliminated, leaving marked those variables that have the greatest influence on the spatial arrangement of the principal component. This analysis is quite telling in how the layers (and thus the excavations) relate to the variables. Again, we can see a certain kind of closeness between the layers 16 and 14.

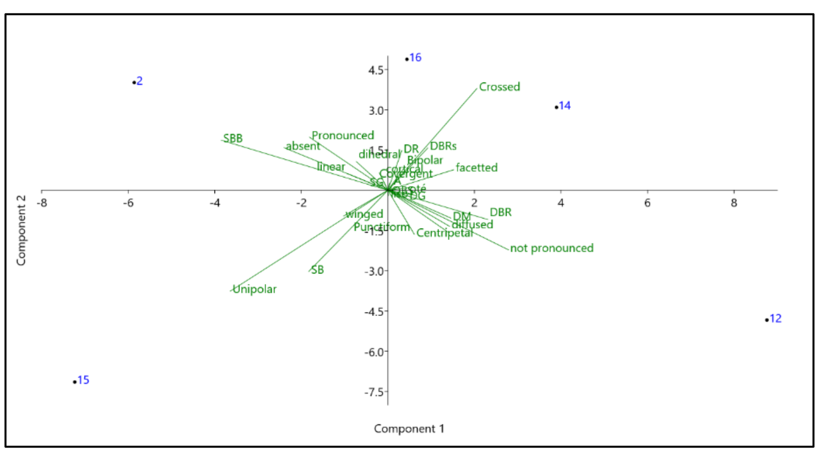


Figure 38 PCA Relation between the technological features and the archaeological layers.

Variables	Principal Components			Variables	Principal Components		
	PC 1	PC 2	PC 3		PC 1	PC 2	PC 3
A				Plain			-0.34729
DBR	0.27424	-0.12951	-0.41636	Oté			0.22734
DBRs	0.10977	0.18744		Punctiform		-0.19464	
DG				Winged	-0.1218	-0.11441	
DM	0.17298	-0.12335	0.19635	Bipolar		0.10329	
DR		0.17582		Centripetal	0.16464	-0.18476	-0.1746
OBS				Convergent			
SB	-0.21701	-0.35924		Crossed	0.24473	0.45098	0.10233
SBB	-0.45748	0.22167	0.18776	Unipolar	-0.43253	-0.44655	
SG				Absent	-0.28527	0.18866	-0.25101
Cortical				Diffused	0.16967	-0.16001	-0.14781
Dihedral		0.12684	0.39175	Not pronounced	0.33103	-0.26377	0.4557
Facetted	0.18034			Pronounced	-0.21543	0.23513	
Linear	-0.11018		-0.22339				

Table 20. Loadings of the 3 PC of the previous PCA.

5.2.2 Relationship between flakes/blades and bifacial artifacts

This research also aims to explore various data to characterize the technological features of flakes that were used in the manufacture of bifacial artifacts. To achieve this, the relationship between all variables and the bifacial artifacts in each layer will be studied. This analysis will help identify which technological features of flakes are related, and which are not related, to the bifaces.

Figure 39 shows the correlation (Kendall) between the layers and the technological features plus the presence of bifacial pieces. This correlation shows that, contrary to what was expected, the bifacial artifacts do not present any type of relationship with the technological features observed in the flakes. There is only a negative correlation with unipolar flake negatives.

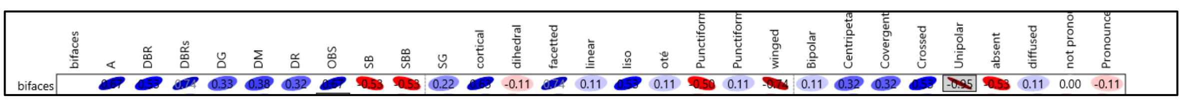


Figure 39 Correlation between the bifacial artefact presence on the layer and the technological features.

5.2.3 General consideration of the statistical analysis

The technological analysis of the Roberto Amador site shows that there are at least two lithic reduction sequences. The first is represented by the production of a small fraction of blades and a second lithic sequence focused on the shaping of bifacial artifacts. Regarding the first reduction sequence, it can be said that the blades produced at the RA site tend to present certain technological characteristics such as plain, dihedral, facetted and punctiform butts. It is also common for these pieces to present absent to diffuse bulbs. On the other hand, the technological and statistical analysis of the bifacial artifacts showed differences. Firstly, the technical analysis supported by frequency studies, suggested a lithic production focused mainly on the production of bifacial elements. Although the frequency of technological characteristics that allow us to intuit a manufacture of this type of elements is not so high, it is representative within the total sample.

Characteristics such as butt preparation for the extraction of flakes, convergent, crossed, and centripetal back negatives, and a tendency to a low frequency of bulb sizes supported the hypothesis of a bifacial workshop.

However, statistical analyses have suggested that the technological features of the lithic products (which were assumed to be flakes from the bifacial shaping), are not entirely correlated with the presence of bifacial artifacts. This situation can be explained in two ways. Possibly, the absence of correlation between the variables and the bifacial artifacts is due to the fact that most of the bifacials present in the study were fractured, which limited the gathering of a greater number of variables. In other words, the fractured bifacial tools were empty in terms of their informative potential regarding some variables, because it was not possible to obtain enough data due to their incomplete integrity. Another reason may be that part of the lithic assemblage does not belong to the manufacture of bifacial artifacts but belongs to a lithic reduction sequence that has not been identified at the site. Also, the information taken from the bifacial artefacts was not enough to achieve a good statistical analysis. This is an important data, because it presents a new panorama that the technological analysis misses completely.

Initially, the morphology of the lithic pieces suggested a similar behavior for the 5 layers or the two archaeological excavations, as can be seen in the dot plots where the morphologies are expressed in a Cartesian plane. However, when applying factorial statistical analysis (PCA) to the morphologies, especially to that of cores and lithic products, a new classification was produced grouping similar metric behaviors for layers 2 (Ex.2) and 12 (Ex.3), and disaggregating layers 14 (Ex.3) and 16 (Ex.3) separately from each other. As for layer 15 (Ex.2), it tended to be close to the center with layers 2 and 12 but keeping a slight distance. This suggests that for cut 3 there is a difference in the way of exploitation and knapping the lithic raw materials in the different layers. And they do not present the similarity shown in the technological and descriptive statistics analysis. With respect the excavation no.2, the result of the PCA suggests a different use, but it does not vary in the distance of the components. Nevertheless, the metric similarities between the lithic elements present in the different layers of the archaeological site RA cannot be underestimated.

If we compare the grouping created by the cluster (Figure 29) and the PCAs of Figure 32 and Figure 34, we can consider that, even though these ways of grouping consider totally different variables, they are consistent at the moment of separating layer 15. Also, it would be necessary to study in greater detail why, while the morphometry PCAs exclude layers 16 and 14, the cluster, which considers all the technological features, groups them together.

In conclusion, this study represents the first step towards classifying and defining the technological, morphological, and metric characteristics of the AR site by using statistical analysis. By identifying these characteristics, it will be possible to achieve an accurately description of the lithic artifacts recovered from the site in future studies.

5.3 Traceological results

5.3.1 Experimental results

In order to interpret the traces of use of the lithic material recovered in the 2 excavations of the Roberto Amador site, a reference collection was made with which an experimentation was carried out on different types of hardness materials, applying different kinetics in various actions. This reference collection was composed of 23 flakes of silicified ignimbrite rhyolite and 6 obsidian blades obtained in a knapping session carried out by PhD candidate Marco Carpentieri and researcher Nicolò Fasser. Moreover, artifact experimentation was carried out by Shananu Kytiar, Tannishta Chokroborty Dayvies Oporto and Tomás Arce. The materials selected for the experimentation activities were fresh bone, fresh meat, and fresh pig skin, soft wood, dried deer antler, pumpkin (*Cucurbita moschat*); and finally grass which was pruned. The results of the traceological analysis of the experimental sample will be presented in the Table 21.

The experiment focused on working stone tools under two conditions. The first one was different types of material with a variable hardness between soft, medium soft, medium hard and hard. For this purpose, a series of materials were selected as described in the experimental protocol in chapter 2. On the other hand, each of the established materials was worked under two main kinematics in use: longitudinal and transverse movements (see material and methods chapter).

The most characteristic traces of use (macroscopic and microscopic) for each of the materials worked will be described below:

5.3.1.1 Butchering and plant work activities (soft and medium-soft hardness)

5.3.1.1.1 Macro-Traces

For the present experiment, the soft hardness materials selected were fresh pork, fresh pork skin, pumpkin, and grass. These materials were worked by experimental pieces knapped in silicified ignimbrite rhyolite and obsidian. The times of use varied with respect to the raw materials and soft materials worked (see Table 21). Like several authors have concluded in different experimental programs (Keeley, 1980; Kononenko, 2011; Van Gijn, 1989; Vaughan, 1985, among others), the present experiment allowed affirming the macro use wear, or the edge removals, are scarce and little diagnostic for interpret use in materials of soft hardness such as fresh meat, fresh skin, as well as cut vegetables and grass.

In particular, the work on fresh meat did not generate any edge removal that could be identified at the macroscopic level. On the other hand, materials such as fresh skin, pumpkin and grass cuttings generated particular detachments in the active edges. These were mainly characterized by being isolated or aligned, rarely superimposed, with a typical morphology of half-moon shape, semicircular and rarely trapezoidal edge removals (see Photo 9). This allows us to intuit the direction of use (González & Ibáñez, 1994; Van Gijn, 1989; Vaughan, 1985). It was possible to establish a direct correlation between edge removals and work kinematics. Regarding the transversal movements it can be say that from the 4 flakes that were worked for butchery activities with transversal movements, 3 recorded traces. From these 3, one present edge removal in both faces, and the other two present edge removal in just one face (the opposite face of the contact edge). In the other hand, and in a very similar way, the longitudinal movements tended to also generate edge removals in both faces of the edge. From 7 flakes worked on butchery activities, 5 generate this type of trace bifacially.

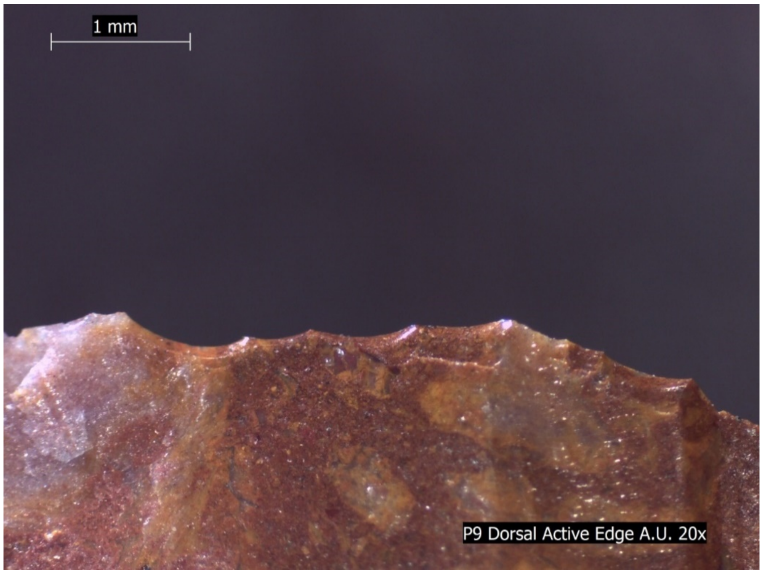


Photo 9 P9 – Dorsal face after use over fresh skin with transversal-unidirectional movement. Its possible to observe aligned half-moon shape of the edge removals.

Photo 10 P10 – Dorsal face after use over fresh meat with longitudinal-bidirectional movement. The edge doesn't show any edge removal or alterations.

N. Tool	Raw material	Worked material	Hardness	Gesture	Activity	Time (min)	Macro traces	Edge damage	Micro traces	Polish	Striae	Orientation	Rounding edge	Post-depositional traces/technological traces
18	S. R.[19]	Skin	Soft	Long-unidirec	Cutting	8	X	X	X	X				
20	S. R.	Skin	Soft	Long-bidirec	Cutting	8	X	X	X		X	Parallel	X	
9	S. R.	Skin	Soft	Trans-unidirec	Scraping	8	X	X	X	X				
24	S. R.	Skin	Soft	Trans-bidirec	Scraping	8	X	X	X	X	X	Parallel		
28	S. R.	Pumpkin	Soft medium	Trans-unidirec	Scraping	8	X	X	X	X			Micro	Polish by percussion
30	S. R.	Pumpkin	Soft medium	Trans-bidirec	Scraping	8			X	X				
31	S. R.	Pumpkin	Soft medium	Long-bidirec	Cutting/peeling	8			X	X			Macro	
21	S. R.	Pumpkin	Soft medium	Long-unidirec	Cutting/peeling	8	X	X	X	X			Micro	
10	S. R.	Meat	Soft	Long-bidirec	Cutting	8			X	X	X	Parallel	Micro	
13	S. R.	Meat	Soft	Long-unidirec	Cutting	8			X		X	Parallel		Polish by percussion
19	S. R.	Meat	Soft	Long-unidirec	Cutting	8			X	X	X	Oblique	Micro	
15	S. R.	Dry Antler	Hard	Trans-bidirec	Scraping	8	X	X	X	X	X	Oblique	Micro	
12	S. R.	Dry Antler	Hard	Long-bidirec	Scraping	8	X	X			X	Oblique		
16	S. R.	Dry Antler	Hard	Long-unidirec	Sawing	8	X	X	X	X	X	Parallel		
27	S. R.	Dry Antler	Hard	Trans-bidirec	Scraping	8	X	X	X	X	X	Perpendicular		
4	S. R.	Dry wood	Hard medium	Trans-unidirec	Sawing	8	X	X	X	X	X	Perpendicular		
1	S. R.	Dry wood	Hard medium	Trans-bidirec	Scraping	8	X	X	X	X				
8	S. R.	Dry wood	Hard medium	Long-unidirec	Cutting	8	X	X	X	X	X	Parallel		
17	S. R.	Dry wood	Hard medium	Long-bidirec	Cutting	8	X	X	X	X	X	Parallel	Micro	
22	S. R.	Fresh bone	Hard medium	Long-bidirec	Cutting	8	X	X	X				Micro	
11	S. R.	Fresh bone	Hard medium	Long-unidirec	Cutting	8	X	X	X	X				
2	S. R.	Fresh bone	Hard medium	Trans-unidirec	Scraping	8	X	X						
5	S. R.	Fresh bone	Hard medium	Trans-bidirec	Scraping	8	X	X	X	X				
OB 2	Obs	Grass	Soft	Long-bidirec	Cutting	15	X		X		X	Parallel	Macro/ micro	
OB 3	Obs	Skin	Soft	Trans-unidirec	Scraping	18	X	X						
OB 4	Obs	Grass	Soft	Long-unidirec	Cutting	15	X	X			X	Oblique	Micro	
OB 5	Obs	Meat	Soft	Long-bidirec	Cutting	12	No		X	X	X	Parallel	Micro	
OB 6	Obs	Fresh bone	Hard medium	Long-bidirec	Cutting	13	X	X	X	X	X	Parallel/ Perpendicular		

Table 21 Summary of the results from the use-wear analysis of the experimental collection. For the complete table se appendix of data base

[19] S.R. = silicified ignimbrite rhyolite Ob =Obsidian

According to this, it’s possible to say that the occurrence of edge removals is not a useful trace for understand the kinematic of use of the artefact on silicified ignimbrite rhyolite that have been used for work soft materials. Notwithstanding, the presence of this trace can indicate a possible use of the tool, which is an important feature for analyzing use wear on lithics.

Tool #	Worked material	Hardness	Gesture	Position of edge damage	Arrangement of edge damage	Morphology	Observations
18	Skin	Soft	Long-unidirec	Bifacial	Isolated	Half-moon	Total breakage of the edge; half-moon; x40 it´s possible observe some half-moons and some trapezoidal edge damage removals showing the direction of use.
20	Skin	Soft	Long-bidirec	Bifacial	Isolated		Creation of edge removals in half-moon shape; breakage of the edge.
9	Skin	Soft	Trans-unidirec	Ventral	Isolated	circular	
24	Skin	Soft	Trans-bidirec	Bifacial	Aligned	Half-moon	
28	Pumpkin	Soft medium	Trans-unidirec	Dorsal	Overlap	Circular and trapezoidal	Some traces can be observed micro polish with a low development and striae very shallow
30	Pumpkin	Soft medium	Trans-bidirec				Don’t show macro traces
31	Pumpkin	Soft medium	Long-bidirec				Don’t show edge removals but it can be seen a rounding edge
21	Pumpkin	Soft medium	Long-unidirec	Dorsal	Overlap	Circular and trapezoidal	Just show a shallow edge rounding
10	Meat	Soft	Long-bidirec				Don’t show macro traces
13	Meat	Soft	Long-unidirec			Breakage of original edge	Show small edge removals in ventral face and rounding edge
19	Meat	Soft	Long-unidirec				Don’t show macro traces
OBS 2	Grass	Soft	Long-bidirec				Isolated small and shallow edge removals
OBS 3	Skin	Soft	Trans-unidirec	Ventral	Isolated	Trapezoidal	Isolated small and shallow edge removals
OBS 4	Grass	Soft	Long-unidirec	Bifacial	Isolated	Half-moon	All around the active edge present edge removals in half-moon shape
OBS 5	Meat	Soft	Long-bidirec				Don’t show macro traces

Table 22 Experimental tools used on soft and medium soft worked materials.

5.3.1.1.2 Micro-Traces

In contrast to the macroscopic traces, the microscopic traces allowed the identification of a variety of different types of use wear such as different polishings, edge rounding and striations. Although these traces were present in most of the experimental pieces, their appearance and development are rather poor compared to traces generated in harder materials. However, it is possible to identify certain characteristics that persist in the traces generated when working soft materials.

Fresh meat

Normally, edges used for butchery activities show an alteration in their cutting edges. However, experimental evidence has shown the low rate of modification of lithic products undergo when working with soft animal tissue, such as fresh meat, cartilage, among others (Keeley, 1980; Odell, 1981; Odell & Odell, 1980; Tringham et al., 1974; Walton, 2019). The traces are only observable at high magnification and it´s highlight a poorly developed polish, which tend to present micro-topographies between irregular and wavy, as well as semi-close meshes[20]. The presence of striations was present in half of the artifacts worked in soft and medium soft materials, so it is an attribute that can allow us to identify the use of archaeological pieces in soft tissues. It should be noted that the generation of these traces had a similar behavior for silicified ignimbrite rhyolite and obsidian experimental samples.

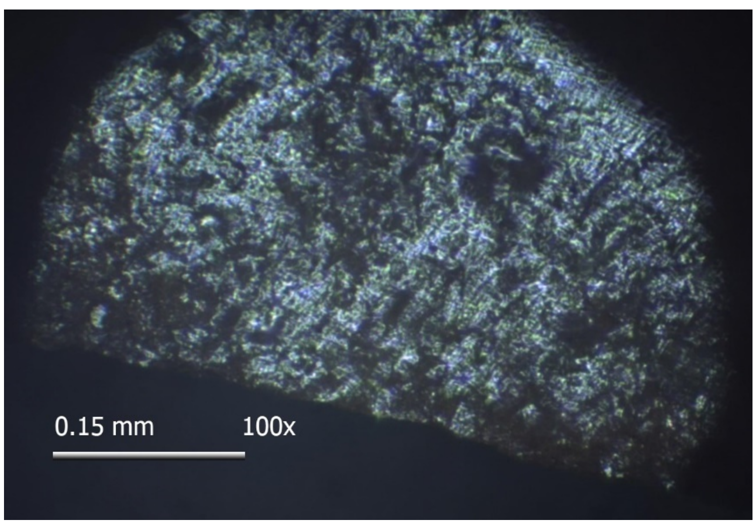


Photo 11 Polish with an open mesh and irregular microtopography produce by meat work. Piece 10 – 100x.

Fresh skin

[20] These types of polish have been reported in other research as polish produce by the work of soft materials ((González & Ibáñez, 1994; Gutiérrez, 1990).

Although the skin is a soft tissue, due to its biological function, it has a greater hardness compared to the internal soft tissues. This means that the resistance it presents against the stone artifacts that interact with it is much greater and will tend to generate different traces to those generated by the rest of the soft tissues. The polishing, which is evident in the work on skins, has the characteristic of having a semi-closed mesh with a micro-topography between irregular and wavy. This polish differs from the work on flesh because it presents slightly larger extensions than the polishes generated particularly by the flesh. Contrary to what would be expected, most of the pieces worked on leather did not show the formation of striations or rounded edges. On the other hand, fresh skin was also worked with an experimental sample of obsidian, which did not show any trace of use.

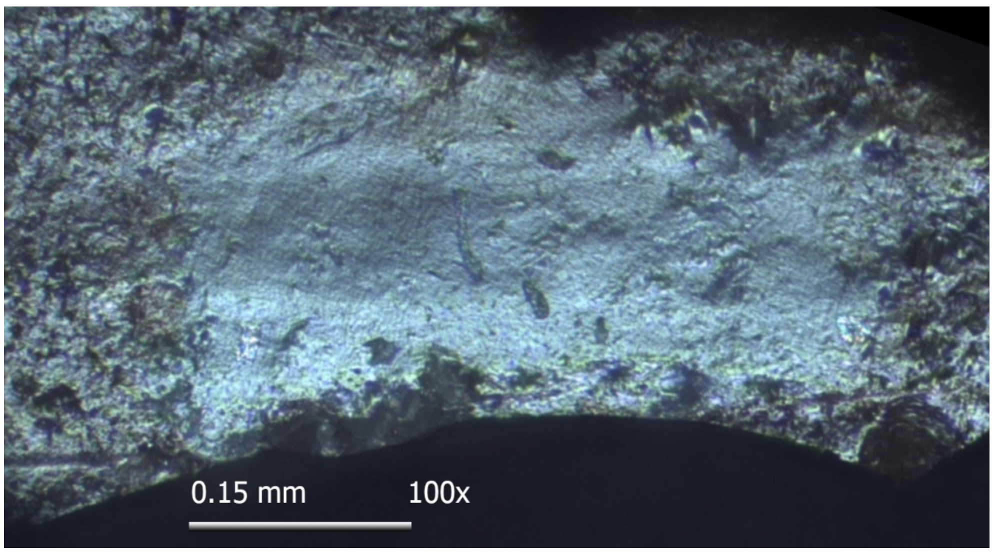


Photo 12 Polish compact and wavy produce by fresh skin. Piece 24 – 100x.

Plants: Cucurbita moschat and grass

Since the importance of plant management and landscape modification in pre-Hispanic societies has been recently demonstrated (Aceituno & Loaiza, 2014, 2015; Espitia & Bocanegra, 2006; Pearsall, 2008; Piperno, n.d.), the experiment considered analyzing possible traces of use produced by these two activities. For this purpose, pumpkin (*Cucurbita moschat*), which is a fruit with a relatively high hardness in its shell, was considered as the material to be used. Also, this is a local fruit from central/south America. Both longitudinal and transversal movements were made on this fruit. The type of polishing present in this material was vague, presenting many similarities with the uses of fresh skin and meat. One difference that stands out is that the transverse kinematic works only marked the contact face of the artifact with the material, and not the opposite face. While the works with longitudinal kinematics marked the active lithic artefacts bifacially. This is an interesting fact because it shows that this type of material is hard enough to mark the faces of the lithic artifacts that come into contact with it. On the other hand, the formation of rounded edges in the active edge for the longitudinal and transverse kinematics have a ratio of 2:1. Finally, the complete absence of striae formation for this material is mentioned.

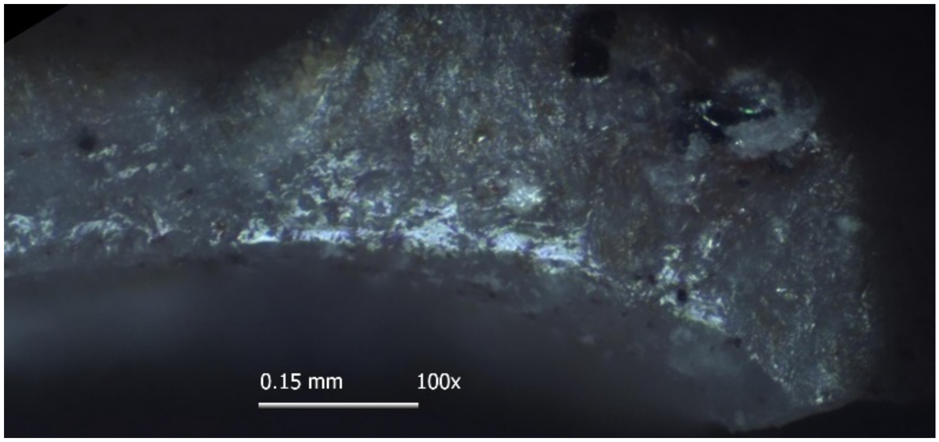


Photo 13 Polish semi-closed and irregular produce by pumpkin. Piece 30 – 100x.

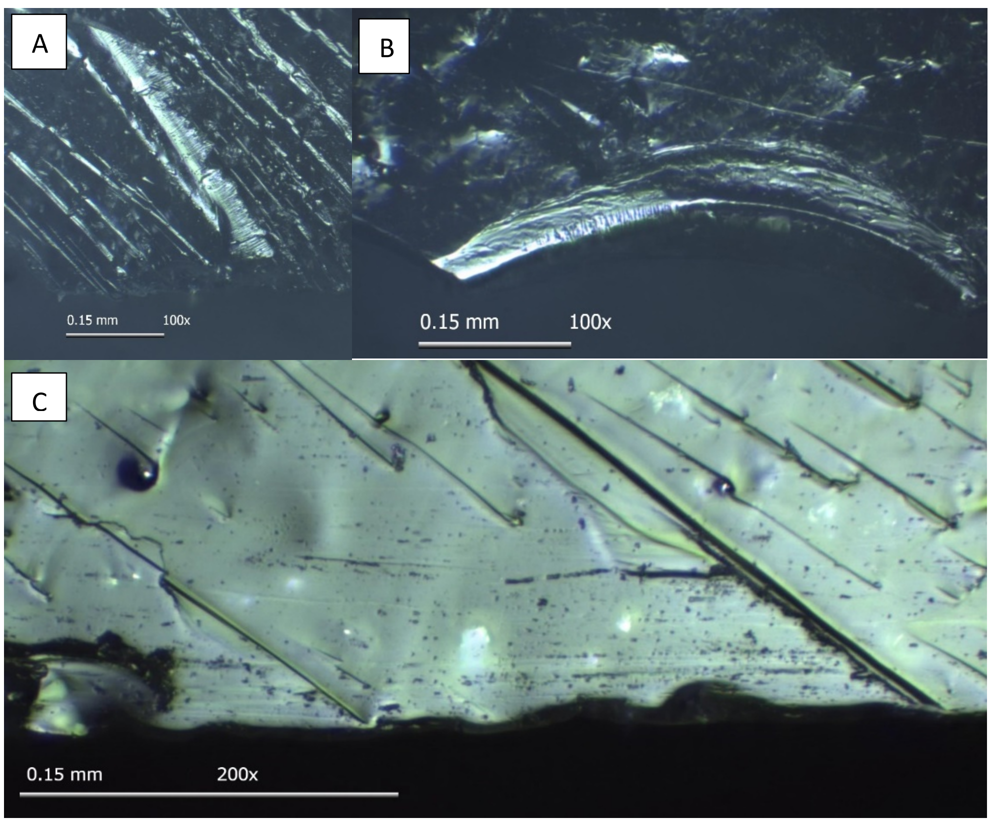


Photo 14 Edge rounding with striae. A and B Piece 2 Obsidian – 100x. C Parallel striae over the active edge - Piece 4 Obsidian 200x

Regarding cut the grass work, this was done exclusively with experimental samples made on obsidian. For this purpose, a strip of grass was pruned for 15 minutes with two different obsidian blades. Regarding the generation of microscopic traces of use, it can be said that this experiment did not generate traces of use of the polished type. This issue has been explained by Kononenko (2011), who in her use wear research in obsidian, determined that at least 40-55 minutes are needed for create a development polish when plants are worked. However, a large number of traces of the striae type (parallel and oblique with respect to the active edge) and a quite strong rounding of the edge were observed. These last characteristics are quite important because no other type of worked material in this experiment evidenced such records (see Photo 14).

5.3.1.2 Work activities on fresh bone, dry wood, and dry antler (medium-hard and hard)

5.3.1.2.1 Macro-Traces

For this experiment, the materials that make up this hardness group (medium hard and hard) were fresh pig bone (femur), dry wood and dry antlers. These materials were worked exclusively with silicified ignimbrite rhyolite in controlled experiments that lasted approximately 8 minutes each. Unlike the experiments developed to observe macro-traces in soft materials, the work with hard materials evidenced a clear use wear. Of the 13 experimental pieces used (12 silicified ignimbrite rhyolite and 1 obsidian), only 1 (ignimbrite rhyolite) did not show macroscopic traces of use or edge removals. It is worth noting that although the only material worked that imprinted Edge removals of trapezoidal type in high frequencies was the dry woodwork. This morphology was present in all 3 materials worked, suggesting the direction of use that the artifact had. Another point to highlight is that unlike the negatives formed by longitudinal kinematic movements on soft materials, the hard materials formed negatives both bifacially and unifacially. On the other hand, the transverse movements continued with the tendency of only marking the opposite face of the one that came into contact with the worked material. Longitudinal movements don't show edge removals bifacially, in fact is much more common that the edge removals appear in just one face of the active edge. This is a notable feature that differentiates the edge removals/kinematic correlation between working over soft/soft-medium and hard-medium/hard hardness materials.

Photo 15 P11 – Ventral face after use over fresh bone with longitudinal-unidirectional movement. The edge shows different types of edge removals (trapezoidal, semi-circular) all aligned.

Photo 16 P11 – Dorsal face after use over fresh bone with longitudinal-unidirectional movement. The edge shows several groups of edge removals with different shapes like half-moon and semi-circular.

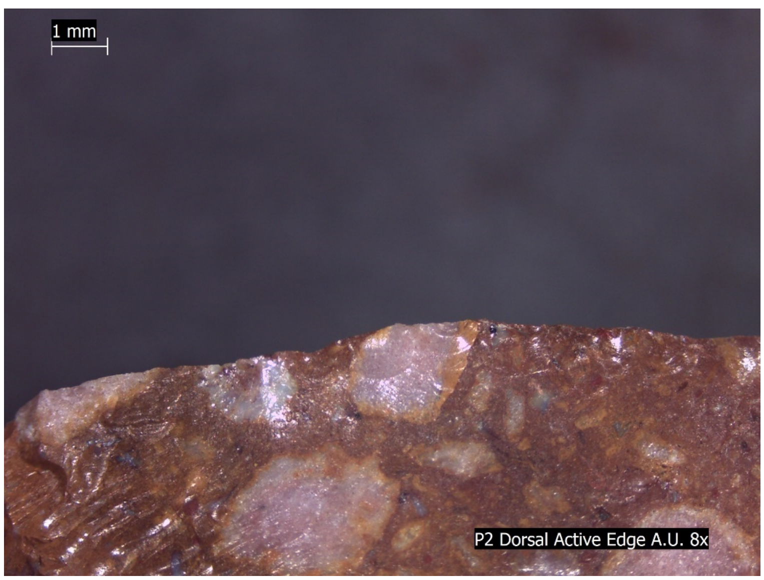


Photo 17 P02 – Dorsal face after use over fresh bone with transversal-unidirectional movements. The edge shows overlapping and grouping edge removals.

5.3.1.2.2 Micro-Traces

As with the micro-traces of use produced by soft materials, hard materials leave traces of use that are much more significant than macro-traces. Of the experimental pieces used on hard materials (13 pieces), all the pieces show at least one type of micro traces (polish, striae or rounding edge).

Fresh bone

From 6 of the pieces worked on fresh bone, one did not show any traces of use at the microscopic level, and other did not show polishing, but did manage to develop striations. The polishes were mainly characterized by having a compact and semi-closed mesh with a smooth to wavy topography. Unlike the rest of the hard materials, the work on fresh bone with transverse kinematics tended to generate bifacial polishes on the lithic artifact and the longitudinal gestures presented polishing exclusively on one of its faces. The striae reported were present in only one piece and had both parallel and perpendicular orientations, which may be due to some particularity of the operator at the time of using the artifact. Finally, only one edge rounding was reported during longitudinal movement.

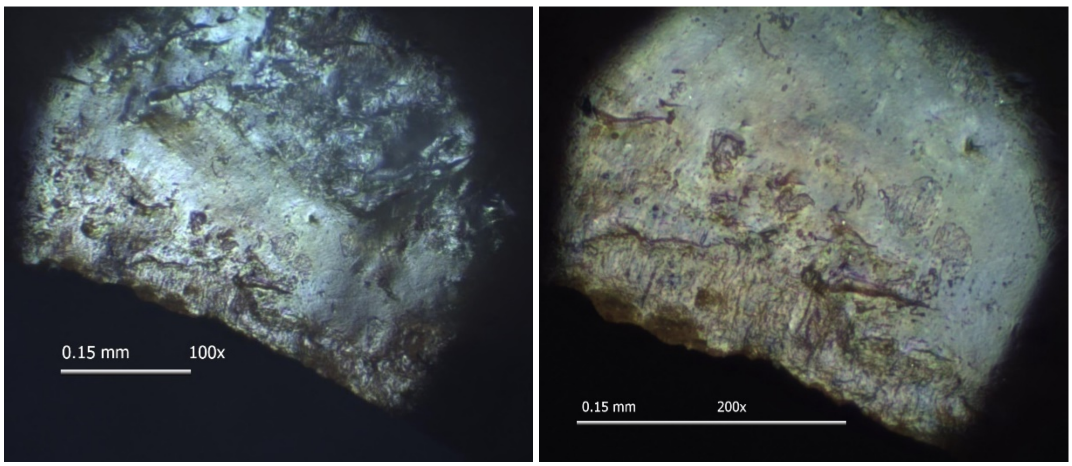


Photo 18 Polish closed and wavy produce by fresh bone. Piece 5 – 100x and 200x.

Dry wood

The dry wood presented in all of its pieces polishing characterized by having a closed and semi-closed mesh with a variable but defined topography (smooth and wavy - only one irregular topography was reported). Unlike the dry bone, the dry wood generated striations in 5 of 6 pieces that were concordant with the kinematic movements recorded for the pieces. This means that the pieces used longitudinally generated one or more parallel grooves while the transverse kinematics generated perpendicular grooves. Finally, edge rounding was only recorded in two pieces. Both of the piece present striae, and polish due to a longitudinal movement (see Photo 19).

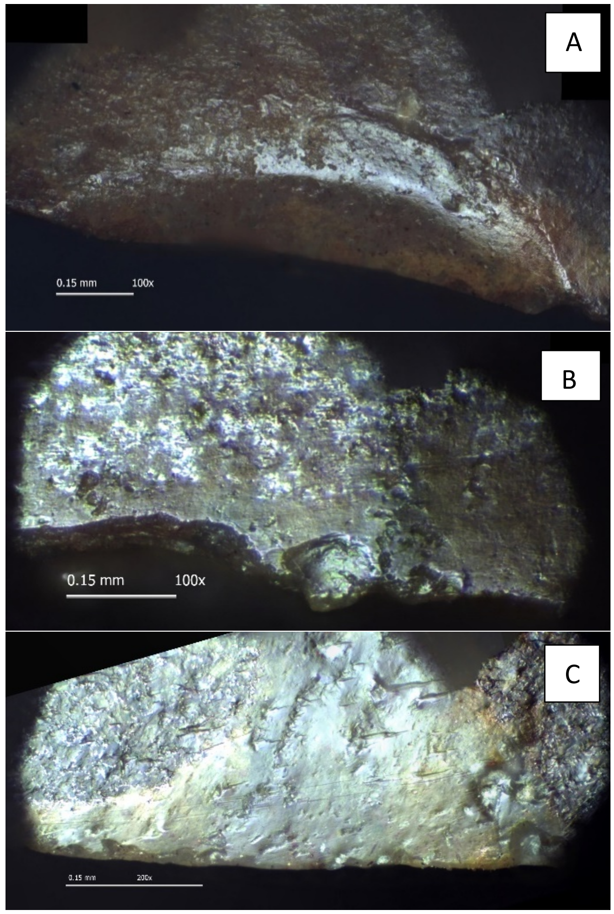


Photo 19 Different types of polish and striae produce by work over dry wood. A – C Piece 17 closed and compact polish with wavy micro-topography 100x and 200x. B – Polish semi-closed and irregular with striae, piece 8 – 100x.

Dry antler

Dry antler was the hardest material worked throughout the experiment and this was visible when recording the type of polish generated when using the lithic artifacts. The polishing of antler was characterized as a polishing with a compact and a closed mesh, with a smooth and a wavy micro-topography. This was one of the easiest polishes to record because of its clear development and shiny (see Photo 20 and Photo 21). As with the dry wood, the work on dry antler generated a large number of striations, leaving a record on all 5 artifacts worked. However, the direction of the striae did not show a concordance with the kinematics worked because the transversal movements tended to print striae with oblique and perpendicular direction, while the longitudinal movements tended to generate parallel and oblique striae. It should be noted that this was the only material worked that produced oblique-direction striations for both kinematics. Finally, only one piece was recorded with edge rounding, so this is a trace that will not be considered diagnostic for the use of hard/medium hard materials.

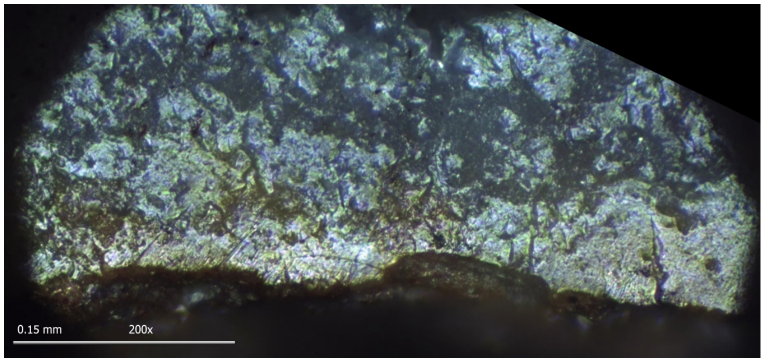


Photo 20 Polish and striae produce by work over antler. Piece 15 - 200x.

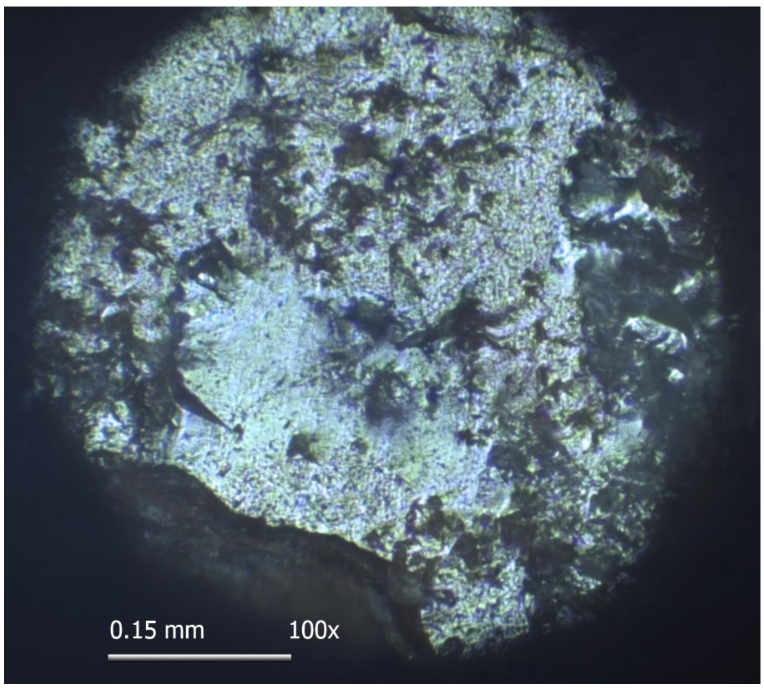


Photo 21 Compact and smooth polish produce by work over antler. Piece 27 – 100x.

5.3.1.3 Statistical tendence of the use wear patterns.

In general terms, it can be said that there is a clear relation between the use wear production and the type/hardness of the material worked. Based on the frequencies of the polishing variables vs. the materials worked, a contingency table can be obtained (see Table 23). With this table, a correspondence analysis (CA) test was carried out, which made it possible to demonstrate the relationship between worked materials and expected polishing variables (see Figure 40). In this test it is possible to make a direct association between hard materials with compact mesh polishing and smooth micro-topography. On the other hand, this test shows that there is a relationship between elements of medium hardness (hard and soft), with closed/semi-closed mesh polishes and wavy micro-topography, however this relationship is much more direct with dry wood. Finally, the work on pumpkin (*Cucurbita moschat*) showed a relationship with open-mesh polishes and irregular micro-topography. This relationship should be studied in the future for a detailed clarification (see Figure 40).

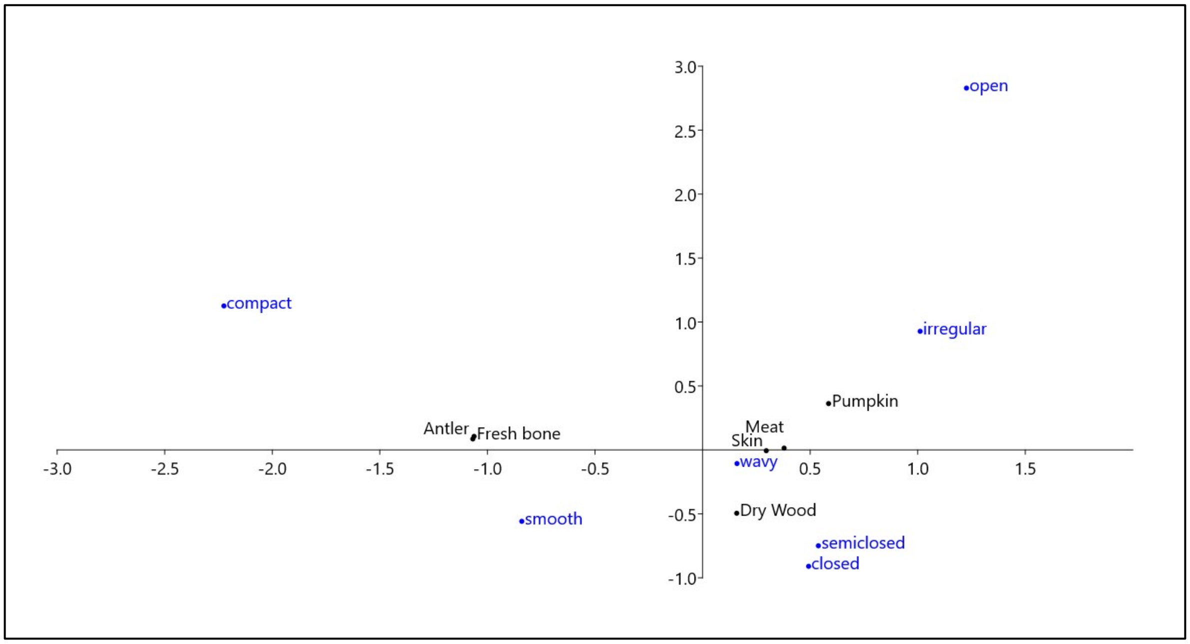


Figure 40 Correspondence Analysis of the worked material vs the polish variables.

MATERIAL WORKED	POLISH							
	Mesh			Micro-topography				
	closed	**compact**	**open**	**Semi-closed**	**irregular**	**smooth**	**wavy**	**Total general**
HARD	1	3	0	0	0	3	1	4
HARD MEDIUM	3	3	0	4	1	6	3	10
SOFT	4	1	1	6	5	3	4	12
SOFT MEDIUM	2	0	2	2	3	1	2	6

Table 23 Contingency table of the association of worked material vs polish variables.

However, for the present investigation we will work with a lower level of resolution to achieve greater reliability in the results. This means that the archaeological sample that will be analyzed based on the experimental data presented here will not be approached in terms of particular worked material (fresh meat, fresh skin, pumpkin, antler, etc.), but will be approached in terms of material hardness. In other words, all trace characteristics (micro and macro) will be grouped by hardness. For this purpose, the correlation test has been run again, grouping the worked materials by hardness. The result is slightly different, where basically compact meshes are associated with hard materials. Medium hard materials are associated to a lesser extent with compact meshes, but mainly with smooth microtopography. Medium soft materials tend to have a close association with irregular meshes and compact meshes. Finally, soft materials have a direct relationship with closed and semi-closed meshes and wavy microtopography (see Figure 41).

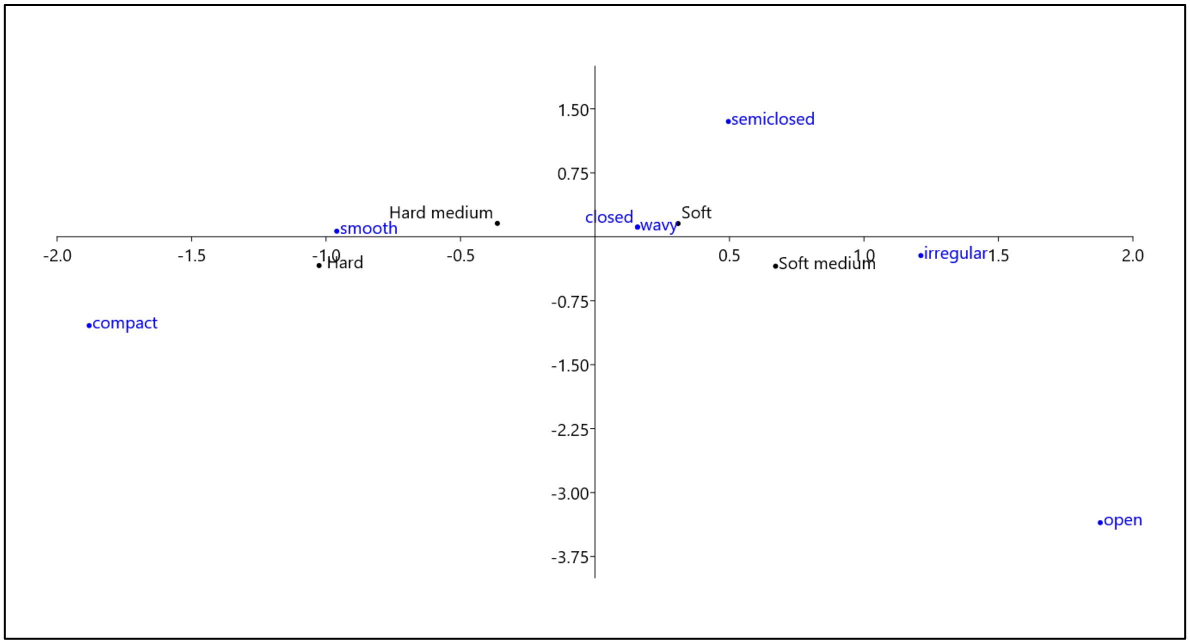


Figure 41 Correspondence Analysis of the hardness of the worked material vs the polish variables.

5.3.2 Archaeological results

As mentioned in the methodology chapter, for the traceological analysis it was decided to take a representative sample of the archaeological collection of approximately 10% of the pieces for each of the pits (ex. 2 and 3). The selection of this sample was guided by an arbitrary and discriminating choice of lithic products by morphology[21]. For taking the sample all the layers of the excavations were used.

In general terms, a total of 234 pieces (among lithic products -flakes type and blade type- and fragments of retouched instruments) were selected for the use wear analysis. From the selected sample, a total of 42 pieces shows macroscopic or microscopic traces. 18 pieces showed only macroscopic traces, meanwhile 16 showed only microscopic traces. A total of 8 pieces shows both type of traces.

Taphonomic alterations at the site are poorly represented. Only 2 pieces were identified with a significant development of patina that prevented the full recording of the active edge on both cases. On the other hand, 2 pieces were identified with a polish produced by a technological process (percussion) during the knapping process. A particular experimental protocol needs to be developed to address these types of issues.

[21] For a better description for the sample selection, see Materials and Methods chapter.

The classification of the use of Roberto Amador's lithic artifacts was made based on the combined analysis of the macro-traces (edge removal) and the 3 types of micro-traces studied (polishing, striae, and edge rounding). In this regard, two different types of approaches can be used to obtain two types of precision in the results (low and high power magnification). The first sought to identify the reliability that the archaeological lithic artifact was used. The second sought to identify the types of materials worked and the kinematics of movement used.

Regarding the first type of result, it can be said that in general terms, none of the lithic pieces analyzed from excavation No. 2 (total of 32 pieces) showed traces of use of any kind. On the other hand, the representative sample from excavation No. 3 presented a total of 11.9% (24 pieces) of used pieces, 8.9% (18 pieces) of probably used pieces and 79.2% (160 pieces) of unused pieces[22]. In summary, a total of 18 elements were probably used and 24 were used with certainty. Also, the frequency of the data suggests an indiscriminate use of lithic pieces with a slight tendency to the expeditious use of flake-type lithic product over the use of blades in pits No. 3 of Roberto Amador site.

Ex. No.	***Used***	***Probably used***	***Not used***	***Total general***
2	0	0	32	32
%	0	0	100	100
3	24	18	160	202
%	11,9	8,9	79,2	100
Total General	**24**	**18**	**192**	**234**
%	10,3	7,7	82,1	100

Table 24 distribution of the frequency of used lithic pieces[23].

The second type of result present the type of material worked with the archaeological lithics artefacts. The type of material worked by the representative sample of excavation No. 3 was led by materials of medium hardness 4.5% (9 pieces), followed by materials of medium soft hardness 3.5% (7 pieces), soft 3% (6 pieces), and in last place were hard materials with a representation of 1% (2 pieces). Finally, in a total of 8.9% (18 pieces) it was not possible to determine the type of material worked and in 79.2% (160 pieces) no traces of use were recorded.

Ex. No.	**Hard**	**Medium hard**	**Medium soft**	**Soft**	**Indeterminate**	**Not used**	**Total general**
3	2	9	7	6	18	160	202
%	1,0	4,5	3,5	3,0	8,9	79,2	100
TOTAL GENERAL	**2**	**9**	**7**	**6**	**18**	**192**	**202**

Table 25 Type of material worked observed on the archaeological sample.

[22] For read about the classification of use of the lithic products see the Materials and Methods chapter.
[23] To see the variables that classified the use of a lithic artefact see Materials and Methods chapter.

According to the experimental use wear analysis (see chapter *4.3.1.3 Statistical tendence of the use wear)*, it can be possible to assigned some of the polish to a particularly worked material. A total of 2 pieces where catalogued as worked over hard hardness materials (see Table 25). The polish register for the layer 16 in the piece with *ID 012* was the most development one being compact and smooth (see Photo 22-left). A similar polish development was recorded on the layer 14 were the piece with *ID 044* also presents a very develop polish and smooth microtopography (see Photo 22-right). According to the experimental record, this particular polish features are linked to the work of hard materials like antler or even hard-medium material like fresh bone.

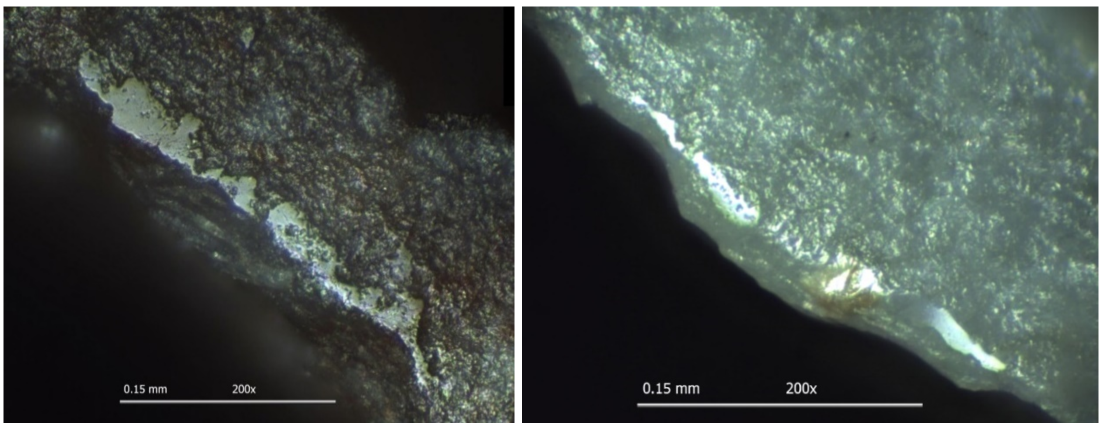


Photo 22 Left: Archaeological sample Piece 12/bag 169 Layer 16– 200x. Compact and smooth Polish. Used over hard material. Right: Archaeological sample Piece 44/bag107 Layer 14 – 200x. Rounding edge. Used over hard material, probably antler.

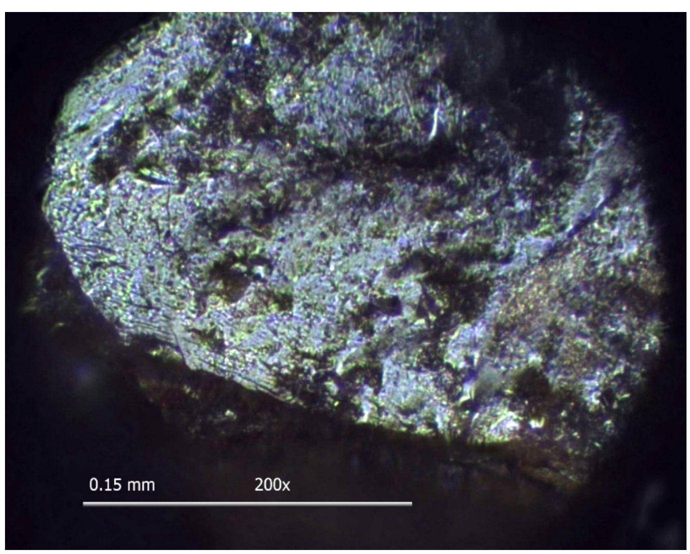


Photo 23 Experimental sample no. 16. Compact mesh and smooth microtopography polish. Working over antler (hard hardness material).

The polish associated to a medium hard and soft hard hardness materials were very difficult to interpret because of the similarities and the abundant of a particular use-feature that this two hardness share. However, there were some pieces that can be plentifully characterized for each hardness. A total of 9 pieces were catalogue as worked over hard-medium hardness material (see Table 25). The piece *ID 107* from the layer 14 present a similar polish that present the experimental pieces No. 8 used for work dry wood (see Photo 24), but with a different kinematic of use, meanwhile the archaeological sample was used in a transversal way (perpendicular striae can be observed), the experimental one was used on a longitudinal way (parallel striae can be observe).

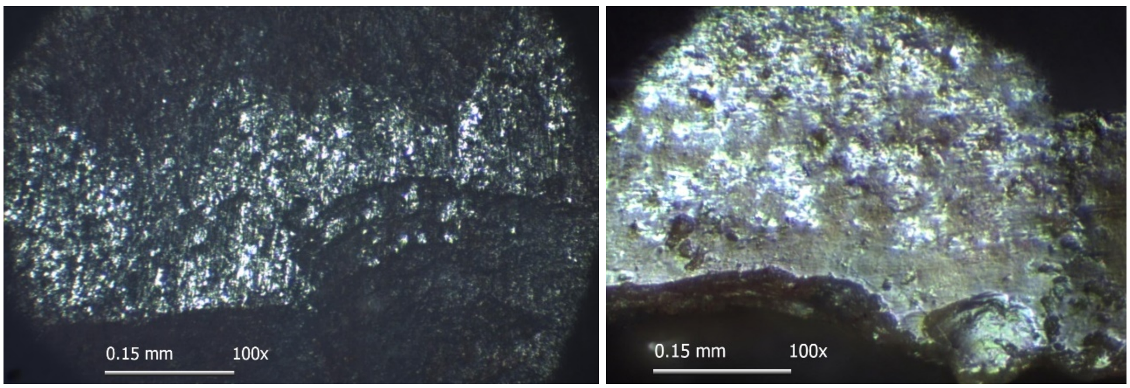


Photo 24 Left: Archaeological sample piece 16b/bag 107 Layer 14-100x. It shows a semi closed mesh and a wavy microtopography and perpendicular striae. Used over dry wood (hard medium hardness material). Right: experimental piece No. 8 used for work dry wood. Present a semi closed mesh and a wavy microtopography and parallel striae.

Also, it was possible to identify some "classic" medium-soft polish on the archaeological sample. A total of 7 pieces were catalogue as worked over soft-medium hardness material (see Table 25). The piece *ID 14* from the layer 18 (bag 182), shows a polish with close mesh and wavy microtopography (see Photo 25). This polish shows similarities between the polish develop in the experimental piece no. 21, which was used for work pumpkin (see Photo 26). It's important to mention again that there is no recording on the archaeological bibliography about use wear studies that work over silicified ignimbrites rhyolites, nevertheless, Gijn (1989) recorded very similar polish patterns on the working of soft plants with flint and silicious rocks.

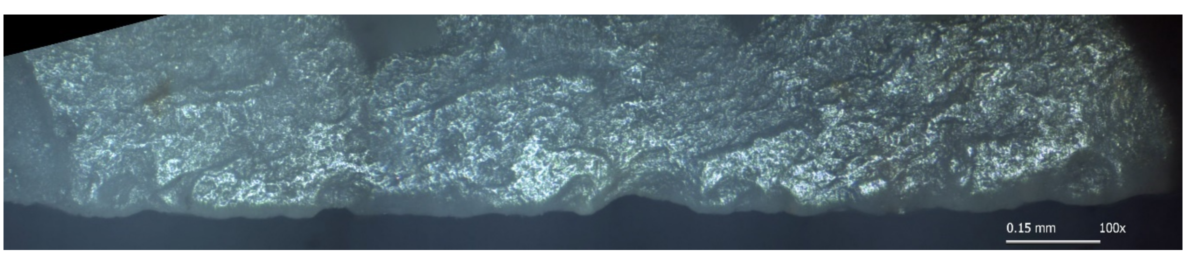


Photo 25 Archaeological sample Piece 14/bag182 Layer 18– 100x. Used over medium soft material, probably over non woody plants (Van Gijn, 1989). *Closed and wavy polish with parallel striae.*

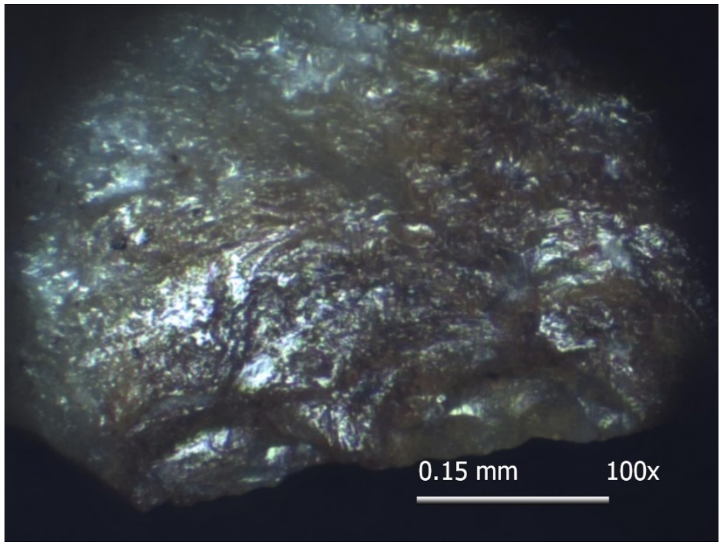


Photo 26 Experimental sample no. 21. Closed and irregular polish. Working over pumpkin soft medium hardness material.

For the last, the soft materials where one of the most difficult for characterize and give a category of use because the development of polish on the work with this type of material requires a lot of working time. A total of 6 pieces were catalogue as worked over soft hardness materials (see Table 25). The problem with this type of polish is that if it's not well developed it looks like what Pal (2012) have catalogue as an indeterminate polish. The piece *ID 13* (bag 136) of the layer 14 shows a polish with a semi closed mesh and irregular microtopography (see Photo 27). This polish looks very similar to the one that was recorded over the experiment with the samples no. 10 and 19, which were used for cutting meat (see Photo 28).

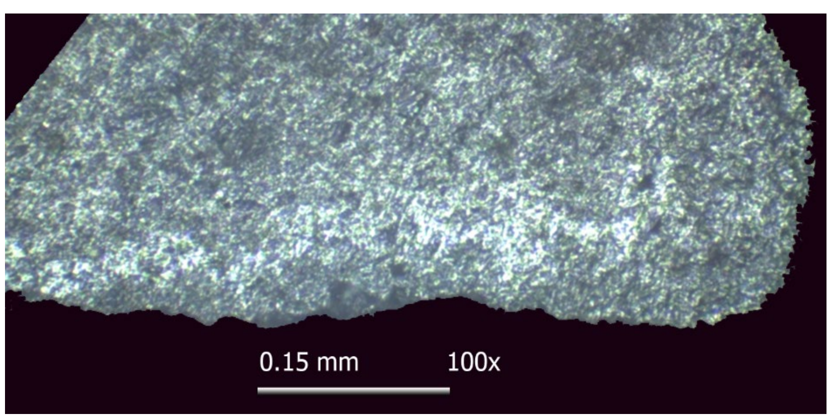


Photo 27 Archaeological sample piece 13/Bag 136 Layer 14 – 100x. Semi-closed and irregular polish. Probably Used over soft worked material.

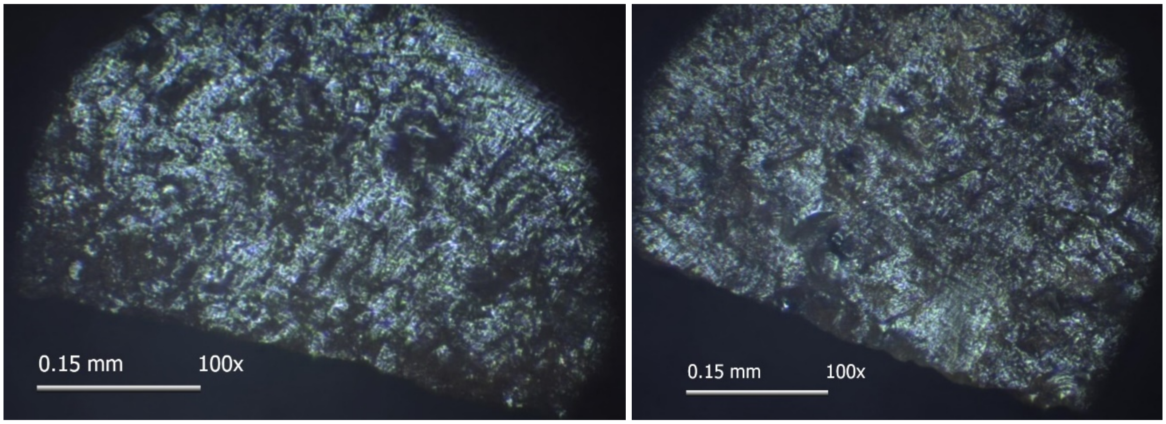


Photo 28 Experimental samples no. 10 (left) and 19 (right). Both present an open mesh and irregular microtopography polish due to the work of cutting meat (soft hardness material).

On the other hand, the type of kinematics of use of the lithic artifacts identified in the representative sample of excavation No. 3 was represented in the first place by longitudinal movements with 4.5% (9 pieces), followed by transverse movements 2% (4 pieces). In 14.9% (29 pieces) of the set that showed traces of use, it was not possible to identify the kinematics of movement (see Table 26).

Ex. No.	**Longitudinal**	**Transversal**	**Indeterminate**	**Not used**	**Total general**
3	9	4	29	160	202
%	4,5	2,0	14,4	79,2	100,0
TOTAL GENERAL	**9**	**4**	**29**	**192**	**234**

Table 26 kinematic of the use on the archaeological sample.

Since one of the objectives of this research is to understand the nature of the lithic reduction of a laminar debitage and fragments of bifacial instruments, it was decided to select and analyze elements belonging to these reduction sequences (blades and flakes/fragments of bifacially retouched instruments) in order to search for traces of use. For this purpose, 51 pieces of complete or fragments blades and 20 fragments of bifacial instruments and 6 retouched flakes where selected. One very important think was that the laminar products and the fragments of bifacial instruments, don't show any type of use wear. The only two fragments of blades that show traces where the two pieces manufactured on obsidian (see below).

Regarding the fragments and complete pieces of blades from the laminar debitage made on silicified ignimbrite rhyolite, it was determined that only 4 pieces showed micro-traces, 2 pieces made on silicified ignimbrite rhyolite and 2 pieces on obsidian[24]. On the first two, a compact and semi-closed mesh was recorded, with a smooth and irregular micro-topography. On the first piece it was identified that the traces of use were very similar to those left by the work of medium hard material

[24] The total number of obsidian pieces for the lithic collection is 4.

like fresh bone. The obsidian archaeological sample show both types of traces, macro, and micro. Regarding the second type of traces, it´s possible to say that the strongest and well develop one were the striae, which presents in parallel and perpendicular (mixed) directions regarding the active edge (see Photo 29 and Photo 30), and the rounding edge (see Photo 30). During the experiment carry on in this research, the only worked material that was able to produce the same micro traces were the cutting grass (soft hardness) for the rounding edge and mixed stria, and working over fresh skin (soft medium), well development striae (see Photo 14). Kononenko (2011), Lewenstein (1981), Walton (2019), and Aoyama (1995) reports very similar traces on obsidian samples working over non woody plants on Oceania for the first one and Central America for the others.

Finally, none of the fragments of bifacial instruments showed traces of use. This is a very important fact because all of these lithic pieces are in a manufacturing stage (pre-forms) or are finish products but are broken due to the final retouching process. It means that this fragments never were used because of an accident during the knapping or are elements that were never retouched for its formalization.

Photo 29 Archaeological sample Piece 2/Obsidian layer 14–100x.Mix striae (parallel and perpendicular). Used over medium hard material.

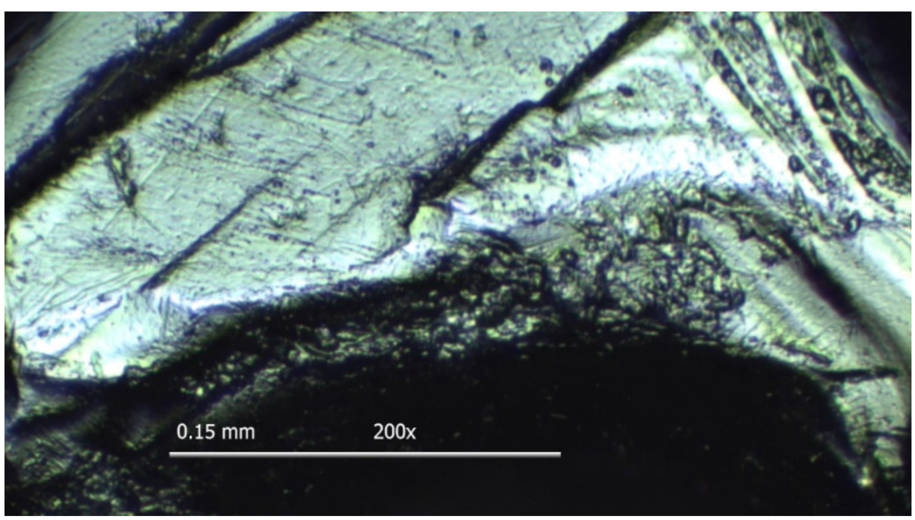


Photo 30 Archaeological sample Piece 1/obsidian layer 14–200x. Rounding edge and oblique striae. Used over medium soft material.

LAYER	Bag number	ID	Edge damage	Polish	Position	Coordinates (van Gijn, 1989)	Mesh	Micro topography	Striae	Position	Orientation	Rounding edge	Worked material	Cinematic
14	107	044		x	ventral	10	Compact	Smooth				micro	Hard	Indeterminate
14	107	016B		x	ventral	3	Closed	Wavy	x	ventral	Perpendicular		Medium hard	Transversal
14	160	013		x	bifacial	9	Compact	Wavy	x	ventral	Perpendicular	x	Medium soft	Transversal
14	160	013		x	bifacial	10	Closed	Irregular	x	ventral	Perpendicular	x	Medium soft	Transversal
14	160	027	x	x	dorsal	8	Semi closed	Irregular					Medium soft	Indeterminate
14	160	040	x	x	ventral	11	Closed	Irregular	x	ventral	Parallel		Medium hard	Longitudinal
14	160	077		x	bifacial	11	Open	Irregular				x	Soft	Indeterminate
14	160	077		x	bifacial	11	Open	Irregular				x	Soft	Indeterminate
14	89	1		x	ventral	4	Open	Irregular					Medium soft	Indeterminate
14	151	2		x			Open	Irregular	x	3	mix	x	Medium soft	Indeterminate
14	102	031		x	ventral	5	Compact	Wavy				x	Medium hard	longitudinal
14	136	04		x	dorsal	11	Closed	Irregular					Soft	Indeterminate
14	136	04		x	dorsal	11	Open	Irregular					Soft	Indeterminate
14	136	013		x	bifacial	3	Semi closed	Irregular					Medium soft	Indeterminate
14	136	013		x	bifacial	4	Open	Irregular					Medium soft	Indeterminate
16	171.1	045		x	ventral	4	Semi closed	Irregular					Medium hard	Indeterminate
16	171.2	063	x	x	ventral	6	Open	Irregular					Soft	Indeterminate
16	171.2	066		x	dorsal	11	Compact	Wavy	x	dorsal	Parallel	x	Medium hard	Longitudinal
16	171.2	070		x	dorsal	4	Closed	Irregular	x	dorsal	Parallel		Medium hard	Longitudinal
16	169	011		x	ventral	11	Closed	Wavy	x	dorsal	Parallel	x	Medium hard	Longitudinal
16	169	012		x	dorsal	8	Compact	Smooth					Hard	Indeterminate
12	63	28	x	x	dorsal	6	Open	Irregular	x	ventral	Parallel	x	Soft	Longitudinal
12	63	63	x	x	dorsal	4	Compact	Irregular					Medium hard	Indeterminate
12	63	160	x	x	ventral	19	Open	Smooth	x	ventral	Mixed		Soft	Transversal

Table 27 Summary of the macro and micro traces recorded on the archaeological sample of Roberto Amado

6 Discussion and conclusion

The general objective of this thesis was to contribute data for the knowledge and study of the lithic technology of the pre-Hispanic groups that inhabited the surroundings of the Mayales River basin, Chontales-Nicaragua. The study focused on the analysis of the lithic material recovered in two different excavations carried out at the Roberto Amador archaeological site. Each excavation had different stratigraphic layers, which were studied individually.

The study of the lithic artifacts focused the research on two different approaches. The first was the study of the development of the technological and technical processes involved in the manufacture of the lithic assemblage of the site, and the second consisted of the use-wear analysis study of the lithic industries.

This chapter will discuss and integrate the results of this research based on the objectives and hypotheses set out at the beginning of the work. For this purpose, the following thematic axes will be considered:

- Study of the reduction sequences of lithic artifacts.
- Analysis of the mechanisms of use formation and the study of the possible context of use.

The axes described above cover different scales of analysis and discussion. Thus, at the level of lithic artifacts, the relationship between the stages of production and the techniques used will be discussed. Likewise, the implications of the recording of different types of use traces within the collection will be discussed, as well as the relationship that can be observed between these two thematic axes. Finally, we will seek to compare and integrate the results obtained with research in the area that has focused on the study of lithic production patterns.

6.1 Lithic technology at the Roberto Amador site

The technological activities developed at the site and the characteristics of the manufacturing processes will be described according to the main trends recorded in the analysis. For this purpose, the lithic reduction sequences identified separately will be discussed, considering their development and change between layers and excavations.

6.1.1 Laminar reduction sequence

The laminar reduction sequence was manifested with different registers in the totality of the layers that constitute both excavations. This reduction sequence is partially represented by elements that show different phases of laminar manufacture.

1.1.1.3 Cores

The cores identified as prismatic type correspond to the lithic elements less represented in the whole assemblage. Regarding excavation No. 2, it was only possible to identify one prismatic core in layer 2. The opposite case occurs in excavation no. 3, which congregates almost all the lithic elements represented in the whole assemblage. 3, which contains almost all the cores recovered at the site, with a total of 4 pieces in layer 12. All the recorded cores were manufactured on silicified ignimbrite rhyolite raw material.

The morphological characteristics of these cores give us several clues about the stages of the laminar reduction sequence present in RA, as well as the exploitation methods used by these communities. A comparative analysis of the length and width modules of the 5 prismatic cores vs. the sizes of all complete blades identified at the site allows us to identify that these pieces still had a useful life in terms of blade extraction at the time of their abandonment. The discard of these pieces should be sought outside of technical reasons, as these pieces do not present morphological/reasonable evidence (broken, exhaustion, absence of percussion platform, or accidents) that would suggest their discard.

One of these reasons could be the hypothesis of the use of a technological strategy expeditive tendency, presenting a reduced investment of effort in the manufacture of tools. This hypothesis could be supported considering factors such as the proximity of the near supply areas of the site, as well as the lack of standardization of the laminar products identified (see next section). Under this premise, it is also possible to imagine a scenario in which the maximization of volumetric production of the prismatic core is not a necessity because the availability of raw materials allows a constant supply.

An important part of the striking platforms showed evidence of preparation in the extraction of blades. This record suggests a degree of expertise in the RA knappers, who had within their range of options, the application of different techniques focused on a precise and careful flake extraction, such as percussion with an organic hammer or pressure technique. Although all the evidence analyzed on the sequence of blade reduction strongly suggests the use of the first technique, some statistical data indirectly suggest the possible use of pressure as a method for blade extraction[25].

The information from the cores suggests that the Roberto Amador site had the particular function of being an exclusive area of lithic exploitation in terms of the laminar reduction sequence. Quarrying activities, as well as the initial phases of lithic production were not identified in the technological analysis. However, it was possible to confirm laminar exploitation at the site. This production presents certain characteristics that allow us to hypothesize about the conceptual and operative scheme of the reduction sequence. The premature abandonment of pyramidal supports poses two scenarios that are not necessarily opposed. First, there may be a tendency to use a technological strategy that prioritizes mass production over quality (there is no evidence of standardization of lamellar supports). Second, the overexploitation of the core (maximization of the volumetric mass) is not a necessity for the knappers since the contiguity in the supply of raw materials allow continuous replenishment. This evidence suggests that the cores would have entered the site in advanced stages of preparation for their exploitation and were only

[25] See following paragraphs.

reconditioned during the exploitation to continue the manufacture of blades, a conclusion that will be reinforced by the data presented below with respect to the laminar lithic products.

It is emphasized that since the behavior of the pieces in this sequence of laminar reduction was uniform in all layers, the discussions and hypotheses presented are also applicable to all layers and excavations.

1.1.1.4 Laminar products

The raw material represented in the products was not only represented by silicified ignimbrite rhyolite, but also 2 types of flint and volcanic rocks such as basalt and obsidian. Little can be said about the products made of flint and basalt due to their low frequencies. Although the lithic products made on obsidian also showed very low frequencies (4 pieces -fragments of blades-), all of them are directly associated with a sequence of laminar reduction as they are fragments of blades. The absence of cores of these raw materials suggests that these products would have entered the site in the form of blades, although it could also reflect a sampling problem or a different discard area for these cores.

Most of the ignimbrite rhyolite laminar products identified in the archaeological excavations presented fragmented integrity (distal, mesial, lateral, proximal, or incomplete pieces), and very few pieces of complete integrity could be recovered. The information obtained from the analysis of these products allows us to postulate that the site was mainly used for the extraction of blades and the adaptation of cores for their continuous exploitation. The activation/reactivation stage of prismatic cores is represented by the low frequency of products cataloged as crested blades, however, the absence of core tablet in the sample is notorious. The null presence of cortex among these lithic products, as well as the absence of prismatic core supports in the preparation stage, suggests that these were entered on the site at an advanced stage of preparation.

The absence of complete blades stands out in the lithic collection in both excavations. This suggests the scenario where the excavation areas were used exclusively for the production of blades, which were later moved to another site for use or subsequent modification into retouched tools. One of the characteristics that stands out among the complete laminar products is the low frequency of distal accidents, as well as the tendency to non-standardization of their sizes and shapes. Regarding the terminations of the laminates, 6.9% presented hinge termination, and the rest presented sharp terminations. The latter reflects an adequate application of force at the moment of extracting the product, so it can be inferred that the carvers had a certain degree of expertise. However, the presence of certain accidents in these products may suggest another scenario, the presence of knappers with little technical skill, or that, given the great availability of raw material, the craftsman did not need to worry about their carving skill and technique during the manufacture. The low standardization of these pieces is also observable in certain technological characteristics such as the butt. The predominance of smooth butt in the complete blades (37.9%) over prepared butt such as faceted (20.7%) or pointed (10.3%) suggests a low investment in the adequacy of the impact platform to obtain standardized products. These evidence, together with certain characteristics described for the cores, allows inferring a sufficient expertise in the flintknapping technique for the manufacture of lithic laminar products focused on a strategy of exploitation over the manufacture of regular products.

The size of the blades is quite diverse, reaching bodies with large and small dimensions. However, medium, and small sizes are the most represented. In this regard, it can be said that the low frequency of large-sized blades reinforces the idea that part of the initial processing of the prismatic cores was developed in a different area. Or these were the predilect size-products sought by the knappers and therefore their representation in terms of frequency is lower given the selectivity and use they may have given to these pieces in other areas. This scenario takes importance due to the study carried out by Debert and Sheriff (2007), who identified a particular new instrument named *raspadita*, which was a type of scraper manufactured over blades and bladelets (Inizan et al., 1999) using soft percussion and pressure flaking over prismatic cores.

Once again, if one compares the relation between blade size vs. core size, it is possible to identify that the pyramidal cores initially presented quite large sizes. This allows us to intuit (indirectly) an extensive production of blades that is not reflected in the archaeological site, which again reinforces the initial hypothesis of the site as an area of a workshop, that probably sought big blade blanks for transport to other areas.

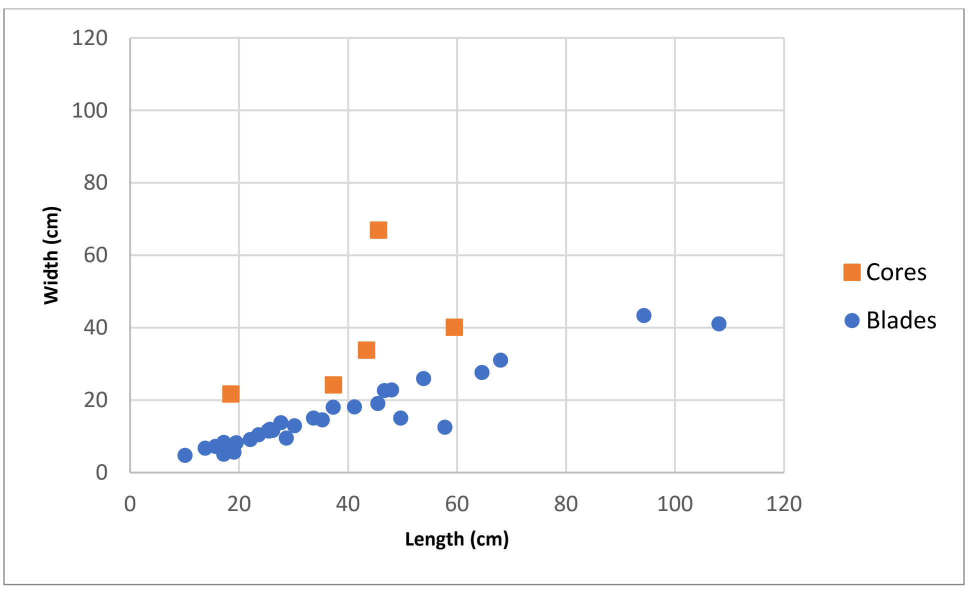


Figure 42 Size comparison between all blades and prismatic cores.

In general, the manufacturing techniques involved in the laminar reduction sequence are various. This can be observed when analyzing the technological characteristics of products such as the bulb. In the Roberto Amador lithic record, diffuse bulbs predominate (58.6%), followed by absent bulbs (31%) and finally pronounced bulbs (6.9%). A high percentage of diffuse bulbs are related to an organic percussion technique and the pronounced bulbs to hard percussion techniques (Andrefsky Jr, 2008; Andrefsky, 2009; Inizan et al., 1999). This suggests that Roberto Amador's knappers used soft, hard percussion and pressure, predominating the soft one during the sequence of laminar reduction, a result that reinforces the hypothesis.

The lithic analysis of the laminar reduction sequence presented in this text is one of the first approaches to understanding the technological and organizational strategies in the region studied from a particular lithic collection.

6.1.2 Shaping reduction sequence

6.1.2.1 Blanks and raw material supply areas

The second reduction sequence identified at the Roberto Amador site consists of bifacial shaping, which presents a record of several of the stages that conform to the reduction sequence of bifacial tools. The diversity of these bifacial tools is wide in the Chontales region (Casale et al., 2007; Castillo Jiménez, 2018; Debert & Sherriff, 2007; Donner et al., 2015; Vlaskamp, 2013), ranging from large-sized tools (they can be interpreted as spear points or unpolished axes/hoes) to medium and small-sized elements (e.g., arrowheads). The bifacial elements represented at the Roberto Amador site are characterized by initial stages of manufacture (preforms), and fragments (distal, mesial, or proximal) of instruments broken during the formalization stage. Likewise, the products from the shaping process attest most of the stages of bifacial instrument production (Inizan et al., 1999).

Unlike the laminar reduction sequence, bifacial shaping has been produced on two different types of raw materials, the main raw material is silicified ignimbrite rhyolite, followed by a small sample represented by silex. This reduction sequence gives us more light on how the lithic raw material could have been used during the manufacture of tools at the Roberto Amador site. Particularly the recovered preforms show the support on which they were made, being these large flakes extracted from cobbles of sizes that must have been above 18 cm (length of the largest preform identified in layer 18[26], excavation No. 3). Particularly a preform recovered from layer 14 (see Photo 7) evidenced the butt of the support under which it was being made. This butt and the support presented technological characteristics (smooth butt, ample thickness) that allowed the identification of a direct percussion extraction technique with a hard hammer. On the other hand, despite the lack of register of cortex in the pieces of this lithic sequence, it is possible to identify in some of them evidence of the exploitation form cobbles taken from water flows. Returning to the bibliographic information of the lithic raw material of the site, it is possible to identify that the primary outcrops of ignimbrite rhyolite are scattered in the region of Chontales and owe their genesis to the network of volcanoes that are located in this region. Very possibly the silicification of these stones had its origin in hydrothermal treatments, which allowed the crystallization of these rocks. Castillo (2018) reports the presence in the area of primary outcrops of this same raw material, but in a state of poor quality due to the absence of crystallization that gives silicification (see Photo 31). In addition to this, the experimentation developed in the present research, recreates a knapping session with cobbles taken from the Mayales riverbed (see Photo 32). These can give us an idea of the types of stones that were selected by these groups to initiate the processes of roughing and creation of blanks, which were later entered into the AR site.

The presence of raw materials in the immediate vicinity of the site (less than 100 meters) is a very important characteristic because it allows an almost immediate supply for economic needs.

[26] This layer was not taken into account in the analysis of this research because of sampling problems.

Photo 31 Wall of Cerro Pedernal. These are in the form of isolated "towers" located on the summit of the hill (Photograph by Alejandro Arteaga, 2016). Taken from Castillo (2018), page 35.

Photo 32 Cobbles from the Mayales River to carry out experimental work of flintknapping during the present research.

1.1.1.1 Lithic Products

As shown in previous pages, the presence of the SHAPING BIFACIAL reduction sequence is represented by preforms, fragments of the final products and remnants of the different stages that preceded the manufacture of the bifacial instruments. Once the supports were defined, they were followed by the 3 different stages of production: creation of a peripheral percussion platform, generation of a bifacial balance plane and the carving of a bilateral balance plane. Finally, it was possible to record, with a relatively low frequency, a series of flakes that testify to retouching, the last stage of the BIFACIAL production sequence.

The first stage, characterized by generating large and thick flakes, pronounced bulbs and usually unprepared butts, presents a lower frequency of products compared to the successive stages. The low frequency of these pieces reinforces the hypothesis of the introduction of supports in advanced stages of preparation for the RA excavation site. In a second scenario, the low frequency of preforms may be due to their discard due to unproductivity resulting from certain accidents during it knapping. Another scenario comes into view if we consider that the frequency ratio of preforms vs. bifacial tool fragments is quite disparate (e.g., ratio of 1:12 for layer 14). In this case, it can be assumed that the knapping was carried out by people with sufficient expertise not to damage preforms during their initial phases.

Once the preform, together with its peripheral percussion platform is formed, it is followed by the shaping of the bifacial and bilateral equilibrium planes. This next stage requires a total change of percussion techniques, as the force control and precision of the percussion stroke must be more accurate. If we again consider the termination or distal zone of the flakes as an indicator of effectiveness in extraction (absence of accidents), we can determine that these phases were carried out with high effectiveness, showing less than 5% of pieces with accidents (e.g., hinge termination). Another technological characteristic of these products that denotes expert processing is the high frequency of processing of stubs.

Finally, once the products were made, they were moved to other areas outside the excavation area. The total absence of finished instruments is an example of this. However, fragments of these bifacial tools are characteristic of the site, which were broken during the last stages of production. Thus, the total sample of bifacial elements is composed of proximal, mesial and distal fragments of bifacials, as well as projectile points and a single specimen that was reconditioned after having broken during the manufacturing process.

None of the fragments of bifacial instruments refit with another piece. If we add the evidence of the existence of a reconditioned fragment, we can suppose that most of the fragments of the bifacial instruments could have been transformed into supports for the elaboration of new tools, evidencing a curated technological strategy with a strong tendency to reuse fractured instruments, at least in their manufacturing stage. This evidence the use of a totally different strategy for the production of bifaces vs. blades.

6.1.3 General considerations

An important component of the work was to test the coded technological characteristics for the application of different statistical tests in order to explore trends and technological variables of the assemblages. This analysis produced several points that should be discussed:

First, one of the important particularities that should be highlighted is that the statistical test showed that a small portion of the sample studied did not correspond to either the laminar reduction sequences or the bifacial shaping. The technological characteristics of this group of flakes do not correspond to the expected particularities of flakes from both lithic sequences, therefore the correlation tests performed separate this small group. If we return to the technological analysis, the presence of 1 disc-shaped core (Arzarello et al., 2011; Inizan et al., 1999; Terradas, 2003) and 2 cores with multidirectional extractions, catalogue by some researchers as opportunistic cores (Nelson and

Binford 1979) may indicate an even more diverse composition at the Roberto Amador site. The lack of remains to characterize and explore these different lithic reduction sequences present should be considered in future research. In this regard, it is worth mentioning that Castillo (2018), managed to identify 3 lithic reduction sequences for the Sabana Grande site, which is also located within the Chontales region. Apart from laminar reductions and bifacial shaping, he identified a small portion of the sample that was carved following a discoidal type of method. This suggests a technological trend in the area, which is focused on the production of bifaces, blades, and supports/flakes debitage by the discoidal method.

Second, in terms of frequencies of technological characteristics, the lithic products did not show great differences between layers. This means that in general terms the behavior was similar for the two excavated areas and their different stratigraphic layers, suggesting a constant use of space as a workshop over time. Nevertheless, the ordination tests, based on the classification of the technological characteristics of the lithic products (only flakes *sensu stricto*), were able to group in terms of similarity the first two layers of both excavations (2 and 12), as well as layers 14 and 16 (excavation no.3) and 15 (excavation no.2).

Finally, the technological analysis supported by the statistical tests was able to conclude the type of space use of the excavated areas in the Roberto Amador archaeological site. Three different lithic reduction sequences were identified, which were made at two different heights of the alluvial terrace on which the site is located. Although they do not share a neighboring space, both areas were used as manufacturing zones for bifacial tools, blades and flake supports (for this last product it is not possible to specify further due to lack of information). While the sequence of laminar reduction suggested the use of strategies that do not invest much in the instrument's formalization, the bifacial shaping suggests a use of conservation of the instruments, even readapting fragments of broken bifacial instruments for use.

6.2 Patterns and context of use of the lithic products from the Roberto Amador site

The general objective of this thesis was to contribute to the understanding of the lithic technology of the prehispanic groups that lived in the Late Holocene (Donner & Geurds, 2018, 2020), on the middle course of the Mayales River, in the region of Chontales, Nicaragua. This second part of the research focused on the analysis of the traces of use in archaeological artifacts in order to explore the type of relationship between the manufacturing context and the context of use. For this purpose, a microscopic-based functional analysis program was developed, a tool that allows us to identify the modalities of use of the lithic artifacts.

There are several factors that influence the formation of use wear, among them are the raw materials exploited and the characteristics of the activities carried out with the instruments. With respect to the selection of raw materials and their use, it has been demonstrated the predilection of the pre-Hispanic groups to use a single raw material, reaching a representation that exceeds 95% in all the layers. The silicified ignimbrite rhyolite is a raw material available in the area with easy access and presents in general terms a high quality for knapping.

For this purpose, it was decided to elaborate an experimental program that would take silicified ignimbrite rhyolite cobbles as raw material for their respective knapping and use in order to observe and characterize the mechanisms of trace formation. In traceological studies, experimentation is a fundamental component to constitute a frame of reference from which to recognize and characterize the traces of use in the archaeological record (Domínguez-Rodrigo, 2008; Gutiérrez, 1990; Lin et al., 2018; Marreiros et al., 2020; Michael Schiffer & Skibo, 1987; Outram, 2008; Shelley, 1990; Tringham et al., 1974).

The experimental work carried out sought to characterize the processes of formation of use wear of this particular raw material on different working materials and different kinematics of movement of the instrument. The first was developed following the classification of hardness initially given by Odell and Odell (1980) for the worked materials (see materials and methods and methodological approach chapters). the second sought to identify the differences in the contexts of production of the traces from different kinematic movements (longitudinal and transverse).

6.2.1 Archaeological collection.

From the beginning of the research, the conception of the Roberto Amador site was of an area destined for the knapping of stone tools, a workshop. We sought to explore this hypothesis from several methodological angles, which is why we developed a traceological study on a representative sample of both excavations, which was selected in part, according to its morphology (seeking to include products of the laminar reduction sequence) and another part, randomly.

It is important to mention again that the traceological analysis was carried out on a representative sample of 10% for each excavation layer. While excavation no. 2 had a representative sample of 32 pieces, excavation no. 3 had a representative sample of 202 pieces[27] (see Table 28). The following discussion of the traceological results has been conducted on the representative sample of 10%. The results of the traceological study showed in excavation No. 3 the existence of lithic products with clear traces of use in 11.9%, and 7.7% of pieces that showed certain traces that suggested a possible use but could not confirm it. This percentage is taken over the traceological sample of the 10% of each excavation. With respect to excavation No. 2, there was no evidence of traces of use in any of the lithic products studied.

This raises two completely different scenarios. The first, corresponding to excavation no. 2, shows an area in which the exclusivity of its functions is not overlapped by different activities other than the manufacturing blades and bifacial tools. The second, excavation no.3 evidenced lithic pieces with traces in each of its levels (2, 12, 14, 16 and 18[28]). Several things can be said about these pieces. The total of the sample with traces of use varied between layers, but the frequencies expressed in percentages present ranges of use quite similar to each other, presenting a percentage of use between 5%-19%. Since this is a representative sample of the total lithic assemblage, similar percentages of use can be expected for the rest of the archaeological sample. Post-depositional

[27] For a more detailed description of the sample selection for the analyses performed in the present investigation, see the Materials and Methods chapter.
[28] For the traceological analysis, samples were taken from all the layers of the excavations, even if they were not taken into consideration for the rest of the analysis (technological or statistical), e.g., layer 18.

processes did not affect the sample, so it is expected that these percentage of frequencies reflect a general behavior of the collection.

EX. / LAYER	ARTIFACT USED	ARTIFACT PROBABLY USED	ARTIFACT NOT USED	TRACEOLOGICAL SAMPLE	ARCHAEOLOGICAL ASSEMBLAGE PER LAYER
EX. 2	**0**	**0**	**32**	**32**	**357**
Layer 2	0	0	32	32	209
Layer 15	0	0	0	0	135
Layer 17	0	0	0	0	13
EX. 3	**24**	**18**	**160**	**202**	**1702**
Layer 12	3	3	38	44	253
Layer 14	13	12	71	96	898
Layer 16	9	1	36	46	404
Layer 18	1	2	17	20	100
Layer 19	0	0	0	0	47
TOTAL	**24**	**18**	**192**	**234**	**2059**

Table 28 Frequency distribution of archaeological lithic products with traces of use in the archaeological context of Roberto Amador.

The patterns of use at the Roberto Amador site, represented by the evidence collected in excavations No. 2 and 3, are areas with expeditious use of the lithic products. This means that these areas, previously characterized as flintknapping zones with lithic reduction sequences of laminar production and bifacial shaping, were places of expeditious use of materials of different hardness materials among which can be interpreted, fresh bone, fresh skin, non Woody plants, meat, and deer antler.

Regarding archaeological excavation no. 2, as previously mentioned, none of the elements analyzed showed traces of use. Regarding excavation no. 3, the following can be said:

From stratigraphic layer 12, 44 pieces were taken for traceological analysis, of which only 6 showed traces. Of these, 3 showed only macroscopic traces (edge removals) while the remaining 3 showed microscopic traces that allowed us to identify that two pieces were worked on soft hard material, and one on medium-hard material. The interpretation of these traces has been given by butchery processes with work on meat and skins.

On the other hand, layer 14 had 96 pieces for their respective traceological analysis. Of these pieces, 25 showed traces of use, 12 with macroscopic traces and 13 with microscopic traces. The work of these pieces was mainly on material of medium soft hardness (5 pieces), soft (4 pieces), medium hard (3 pieces) and hard with only one piece. This is the layer with the highest representation of traces of use, but it is also due to the fact that it is the layer with the higher frequency of lithic elements. The interpretation of the use patterns of this layer are relatively similar to those presented in the upper layer, a use focused on butchery activities (fresh meat, fresh skin, and fresh bone), as well as in the processing of non woody plants, and a possible work on wood elements.

Layer 16 had 46 pieces for the traceological analysis, reporting traces of use only in 10 pieces. Only over one piece was recorded macroscopic traces (Edge removals), and 9 pieces with microscopic traces. The work on these pieces was carried out on materials of medium hard (5 pieces), soft (2 pieces), hard and medium soft shared the frequency of a single piece. Unlike the rest of the layers, this one presents a pattern of use that moves away from butchery to focus on woodworking, followed by butchery activities and work on non woody plants, and antlers or hard materials.

Layer 18 had 20 pieces for the traceological analysis, showing use only in 1 piece and a probably use (represented by only macro-traces or edge removals) in just 2 pieces. The rest of the pieces (17) didn't show any type of use wear that allow us to interpreted use. The only piece with clear use wear was worked over a medium hard hardness material, and the traces present a high similarity with the traces developed for the woodworking. For the other 2 pieces that show only macro traces, it´s impossible to identify the worked material, but due to the similarities of the edge removals, it can be said that they were use for work materials that have a hardness of medium hard or hard.

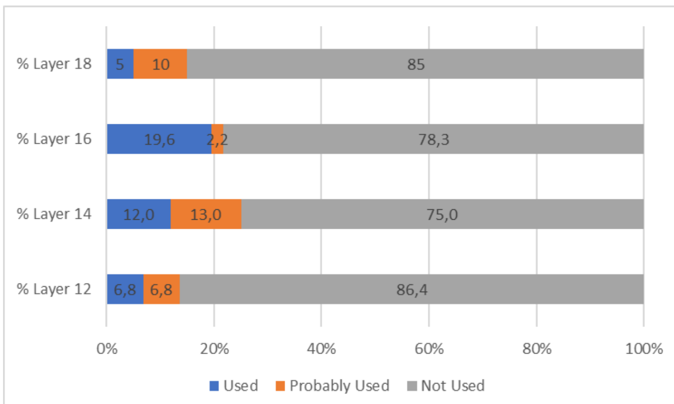


Figure 43 Percentage of used lithic products per layer.

Considering only the microscopic traces, the frequency of use in terms of percentage tends to be slightly similar for layers 16 and 14 with 19.5% for the first and 15.7% for the second. While layer 12 and 18 presented a frequency of use in percentage of 6.8% for the first and 5% for the second.

Finally, there were no signs of use found on any of the bifacial retouched tool fragments. This holds significant significance as these stone pieces are either in the process of being shaped (pre-forms) or are completed items that were fractured during the final retouching phase. Consequently, it can be concluded that these fragments were never utilized due to accidental damage during their crafting, or they represent components that were intentionally left unretouched for their intended final form. However, as will be shown below, it can be the response of a particular technological strategy.

One of the characteristics that should be highlighted is the presence of a single trace in the pieces that showed use wears. This evidence allows us to explore even deeper into the technological strategies adopted by these groups. The fact that a flake was used exclusively for a particular and determined task allows us to infer once again that the contexts of use within the lithic reduction sequences were secondary and were produced under an opportunistic logic (*sensu* Nelson, 1991). According to several authors (Binford, 1979; Nelson, 1991; M. Shott, 1986), opportunistic behavior is a response to the unforeseen, and tends to be differentiated from technological expediency, since the latter is a planning made possible by an adequate supply of raw materials that reduces manufacturing costs in scenarios where time and supply are not a concern. Therefore, and based on the traceological and technological results, during the manufacture of bifacial tools and laminar products, certain situations may have arisen that required the opportunistic use of an edge (cut some supplies, adequate a different tool to continue the knapping process, etc.). The analysis of traces of use determined that certain lithic products were used in a wide range of materials such as butchery activities (meat cutting, skin and bone scraping, possibly for the extraction of the bone marrow), work on nonwoody plants (possible processing of some fruit or vegetable), as well as eventual work in hard materials such as the adaptation of some instrument in hard wood or dry antler (strikers/hammer). After their use, these tools were immediately discarded. Since this behavior is unplanned and does not produce products that last, little effort should be invested in their design/preparation, or a shaping flake may become an opportunistic tool.

	Length (mm)	**Width (mm)**	**Height (mm)**
Min	13,2	11,5	0,8
Max	56,2	55	16,7
Mean	31,6	27,30	5,7
Std. Error	1,6	1,4	0,4

Table 29 Summary statistics of the 42 lithic products that present any type of use wear.

It is possible to identify that most of the pieces that show traces of use, do not have a large size. The maximum length reaches 56.2 mm, the maximum width reaches 55 mm, and the maximum thickness reaches 16.7 mm. The average of these lengths for these pieces can be seen in Table 29. It can be observed that in general terms, the products selected to execute those unforeseen tasks during knapping were mainly pieces of reduced dimensions. These physical characteristics, like small size, small active edge, limited number of active edges defines what different authors have defined as low versatile artifact (Binford, 1979; Nelson, 1991; M. Shott, 1986; M. J. Shott & Sillitoe, 2005).

6.3 The Roberto Amador lithic assemblage in the archaeological context of the Chontales region, Nicaragua.

Although there have been several works that refer to the importance of lithic materials in the Chontales region (Arteaga, 2017; Casale et al., 2007; Debert & Sherriff, 2007; Donner et al., 2015; G. McCafferty, n.d., 2008; G. McCafferty et al., 2006; S. D. McCafferty & McCafferty, 2008; Steinbrenner et al., 2021; Van Dalen, 2018; Vlaskamp, 2013), there have been few that have addressed the study of different collections (Castillo Jiménez, 2018; Gerstle, 1976; Van Dalen, 2018). This is a rather particular situation since the record of several surface assemblages with evidence of bifacial tools, flakes, blades, and retouched tools have been reported in different areas throughout the region (Arteaga, 2017; Donner et al., 2015; Van Dalen, 2018).

Despite the few works focused on the study of lithic assemblages carried out in the middle of the last century, as well as at the beginning of the present century for the Chontales region, this work will seek to make a comparison between results.

It is important to highlight the effort of Gerstle (1976), in studying the behavior of the lithic technology of the archaeological site of Sabana Grande (Chontales region). His research focused not only on typological and technological lithic analysis, but also by the intention of determining the use of certain instruments from the reading of macroscopic traces of use such as edge removals and edge angle. The traceological analysis did not present an experimental program but based its postulates on the results of researchers such as Semenov (1964) and Tringham et al., (1974) , among others, which is why it was determined that these results would not be considered for this research. On the other hand, Gerstle was able to determine, from the combination of statistical analysis with technological and traceological variables, that the bifacial tools tended to be reused by the communities that inhabited the Sabana Grande site. Roberto Amador's lithic collection also showed evidence of one recycle of fractured pieces of bifacial tools for create a new one (see results chapter). The work presented a specimen of a fractured bifacial instrument, which was recycled by manufacturing a trapezoidal bifacial (see Photo 8). This suggests that the technological strategies in the Chontales region tend to the reuse of lithic bifacial instruments, which is concordant with the results present in the present work. It is necessary to investigate whether this technological behavior is replicated for other types of lithic products such as retouched tools or flakes.

On the other hand, the evidence presented in this work is also consistent with the evidence recorded by Castillo (2018) for Unit 1 of the Sabana Grande locality, where he reports the presence of a wide spectrum of lithic reduction sequences, suggesting the use of diverse technological strategies. This would evidence a specialization in the economic trends of these groups, indicating an organizational strategy that includes the manufacture of specialized pieces, but also evidences an opportunistic use in the use of non-predesigned pieces to execute unforeseen tasks. The relationship between Roberto Amador and Unit 1 of Sabana Grande (the site worked by Castillo) is closer if we consider that both sites are the ones that have reported the highest frequency of lithic material and bifacial pieces for the area. However, due to the higher frequency of complete bifacial elements reported for unit 1 of Sabana Grande, Castillo focused his research on the understanding of the different stages of manufacture of bifacial tools, proposing a detailed reduction sequence in the production of these instruments. In this regard, a great similarity can be seen in the way these tools were made with those of Roberto Amador. This could begin to establish the data required to begin to hypothesize about the types of population or cultural groups that inhabited the region of Chontales. Was the region inhabited by the same group with a broad territorial and spatial spectrum? Or was the region inhabited by several groups that share cultural patterns?

In recent years it has been proposed that in the Chontales region there was a relationship between surface lithic assemblages and soil fertility, showing a positive correlation between the two (Van Dalen, 2018). Evidence proposed under the premise of *Lithic Mulch Agriculture*, which have been defined as the covering with different petrous elements (natural: pebbles, cobbles, tabular fragments or anthropic: knapping lithic products) fields and gardens with stones, pebbles, cinder and similar lithic materials is a variant agricultural strategy that has been used to evade drought and increase crop yield (Lightfoot, 1994, 1996). This evidence is based on the archaeological data collected in a regional surface survey, and on the data obtained in the pedological characterization of the surveyed areas, as well as at regional level.

Van Dalen (2018) has recorded that mulching in the Chontal region was carried out with different types of wastes and lithic products from knapping, suggesting that this relationship (lithics - fertile soil) allows us to intuit a strong link with agricultural processes. However, the present investigation was not able to identify a strong relationship between the Roberto Amador lithic assemblage and economic activities that suggest processes linked to agriculture. The work of wood and some vegetables is one of the conclusions of the traceological program, but the frequency of their appearance does not allow us to support the idea proposed by Van Dalen. In addition, the abundant presence of lithic elements has a technological explanation (products of different lithic reduction sequences), and no direct relationship has been found between these lithic products and their use and disposal to improve the quality of soils for agricultural processes. However, it is considered necessary to continue exploring Van Dalen premise, from a technological and traceological perspective, since the regional relationship between lithic assemblages and fertile land is evident in the light of Van Dalen research.

6.4 Conclusions and Future perspectives:

All the information presented in this work provides different types of data that help in the interpretation of the social and economic reconstruction of the communities that inhabited the Chontal region during the Late Holocene (Donner & Geurds, 2018, 2020). Although this research focused exclusively on the study of Roberto Amador's lithics, we were able to generate different types of data that allow us to intuit both social and economic aspects. In the light of the results and the discussion (presented above), several perspectives arise:

Roberto Amador is a site that is still under study and for which there is not much published data. The only archaeological campaigns that have been developed have taken place in 2017/2018. To date, several of the recovered evidence are still being analyzed (ceramics, palynological, dating, among others), which will allow us to deepen, confirm or refute the postulates generated by the lithic analysis.

The technological, statistical and traceological evidence, in combination, present a particular panorama for the Roberto Amador site throughout its different stages of occupation, evidenced in the two excavations carried out. Undoubtedly, throughout the history of the site, it has been used as a lithic manufacturing workshop that responds to particular needs. This occurs both in the area of excavation No. 2 and excavation No. 3. The location of this lithic workshop is evidenced by the remains of the different lithic reduction sequences identified, some of which show specialization in manufacture (bifacial tools and laminar supports), and another presents a reduction sequence that seeks a discoidal type of exploitation of the supports. The variability of lithic products manufactured by these societies, together with the different tools reported for the area (Debert & Sherriff, 2007; Gerstle, 1976), suggest a specialization in the consumption of lithic raw materials.

Despite this, an opportunistic behavior was also evidenced in two different lithic scenarios: the first refers to the reuse of certain instruments that accidentally broke; and second, an opportunistic use of certain lithic products to develop tasks and activities on different materials was evidenced. It is important to emphasize that these lithic products were not made for that purpose, but rather the immediacy and need to develop an unforeseen task during the knapping sessions made the craftsmen use flakes that were not created for that purpose. Among the tasks that these flakes developed were butchery work (cutting meat or skins for consumption), non-timber plant work (possibly vegetables for consumption), wood and antler work (possibly making or adapting instruments such as hammers or pressure flaking tool).

Another evidence that suggests the use of these two areas (excavation 2 and 3) as lithic workshop zones is the total absence of complete final tools. The manufactured pieces (for the bifacial instruments) and the blade supports/blanks were transferred to other areas for their respective use.

Finally, the similarity in the composition of the lithic assemblages in Roberto Amador and Sabana Grande, evidence similar practices in different areas of the Chontales region, thus suggesting an inhabitation of the space by the same community or communities that presented the same needs and that were dealing with similar lithic technology.

Future perspectives:

Regarding the use wear analysis, undoubtedly, the perspectives for future research in traceology should be pointed in two directions. The first will be the analysis of both experimental and archaeological pieces, from a combination of different electronic microscopes due to the advantages they present:

- Image quality improvements.
- Higher magnifications and increased focal field.
- Improvements in the analytical capacity of the observed parts.
- Improvements in the ability to quantify information from the observed pieces.

The constant appearance of these advantages has been possible thanks to the continuous technological innovation in electron microscopy. Thanks to this technological development, several traceological investigations have shown a great capacity to analyze not only traces of use, but also the appearance of residues of materials worked with lithic instruments (Álvarez et al., 2012; Borel et al., 2014; González & Ibáñez, 2003; Grace et al., 1985; Hernando et al., 2020; Pedergnana et al., 2020; Pedergnana & Ollé, 2017).

In the last decades there has been a development in different proposals for doing a quantitative analysis of images of the active edges, not just for the record and analyze the use-wear, but also for understanding the generation of traces in different steps of the use of the tool (Ollé & Vergès, 2014). This presents certain advantage because it seeks the objectives in the interpretation of the traces study, a big discussion given on the 70 and 80 decades (Álvarez et al., 2012; Marchena, 2021).

The integration of digital 3D microscopies with the optical and the electronic ones have showed not just a better understanding of the use-wear traces and residual analysis, but also like Martín-Viveros and Ollé (2020) have pointed, it presents an important result for didactic purposes.

Finally, it is worth mentioning the importance of continuing the efforts to understand the lithic processes that took place in the Chontales region, since the evidence presented here, as well as the evidence obtained by different researchers, has shown technological strategies that are more complex than those initially proposed by Gerstle in the middle of the last century.

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8 Appendix A

This attach file has 3 different database presented in a digital format (.xlsx format).

1. Lithic technology analysis.
2. Use wear database of the archaeological samples.
3. Use wear database of the experimental collection.