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On wedges and bones: Archaeological studies of use-wear and residue analysis from Late Holocene occupations in the Southern Pampean Hills (Alero Deodoro Roca, Córdoba, Argentina)

Roxana Cattáneo[a,*], Marisa Martinelli[b], Andrés Darío Izeta[a], José María Caminoa[c], Thiago Costa[a], Andrés Robledo[a]

[a] Instituto de Antropología de Córdoba (IDACOR), CONICET-Universidad Nacional de Córdoba y Museo de Antropología, Facultad de Filosofía y Humanidades, Universidad Nacional de Córdoba, Avenida Hipólito Yrigoyen 174, 5000 Córdoba, Argentina
[b] Departamento Química Orgánica, IMBIV – CONICET, Facultad de Ciencias Químicas, UNC, Edificio de Ciencias II, Ciudad Universitaria, 5000 Córdoba, Argentina
[c] Departamento de Antropología, Facultad de Filosofía y Humanidades, Universidad Nacional de Córdoba, 5000 Córdoba, Argentina

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ABSTRACT

The aim of this paper is to present the results of complementary studies on a type of lithic tool: the small wedge, trying to understand their use and, particularly, the kind of worked material during Late Holocene times in the central region of Argentina (ADR archaeological site). FT-IR spectroscopy on residue recovered from tools edge surfaces and functional analysis of microwear were used as a crosscheck methodology for integrated analysis, including some experimental data. According with the analytical results, we propose that this type of instrument was used either as a controlled way to split camelid phalanges to use them as raw material for tool manufacture or marrow extraction.

1. Introduction

In a previous paper, one of the authors of this work (RC) used the potential of physicochemical studies as a generator of primary data oriented to investigate the relationship between people and objects in the past (Cattáneo, 2009). Methods like FT-IR (Fourier Transformed Infrared spectroscopy) offer the possibility of characterizing bulk chemical compositions that have proved advantageous in 'fingerprinting' the sources of certain classes of organic residue, such as ambers and resins and their derivatives (e.g. Beck et al., 1965; Lambert et al., 1985). Evershed (2008) described an archaeological biomarker revolution in agreement with the excellent results obtained in the characterization of the origin and nature of organic remains attached to archaeological objects. The archaeological information contained in organic residues is represented by the biomolecular components of the natural products that contribute to the formation of a given residue. In that sense, during the last decades the study of tool function has been accompanied by the development and use of other techniques, helping to support results with a crosscheck methodology and integrated results (e.g. Fredengren, 2013; Babot et al., 2013).

Following van Gijn (2014), we understand that the interconnectivity of tools and objects in a larger technological and hence cultural system potentially generates an extraordinary degree of complexity and variation. Hodder (2014) has defined this kind of relationship, that entangles people and things in a post humanist approach, "…as the sum of four types of relationships between humans and things: humans depend on things, things depend on other things, things depend on humans, and humans depend on humans". In this definition, it is accepted that humans and things are relationally produced. Then, studying "things", defined as tools, would allow us to understand these four types of relationships and thus gain greater insights into the role of the human actors and their actions situated in time and space. In this sense, actions are delimited by defining the basic motion of use through a mixture of variables, such as tool's edge morphology, polish distribution, and linear features or striations (Lozny, 2005). Yet, they are also delimited by the study of ancient residue remains.

In view of this, the aim of this paper is to present the results derived from exploring the relationship between a particular type of tool (the small wedge, which contained archaeological residues) and the probable worked material (bone), mediated by the actions and gestures produced by human behavior. Thus, we have attempted to understand the use of the quartz small wedge (made from bipolar cores in most cases) recovered from the Late Holocene archaeological components of

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* Corresponding author.
E-mail addresses: rcattaneo@ffyh.unc.edu.ar (R. Cattáneo), mmartinelli@fcq.unc.edu.ar (M. Martinelli).

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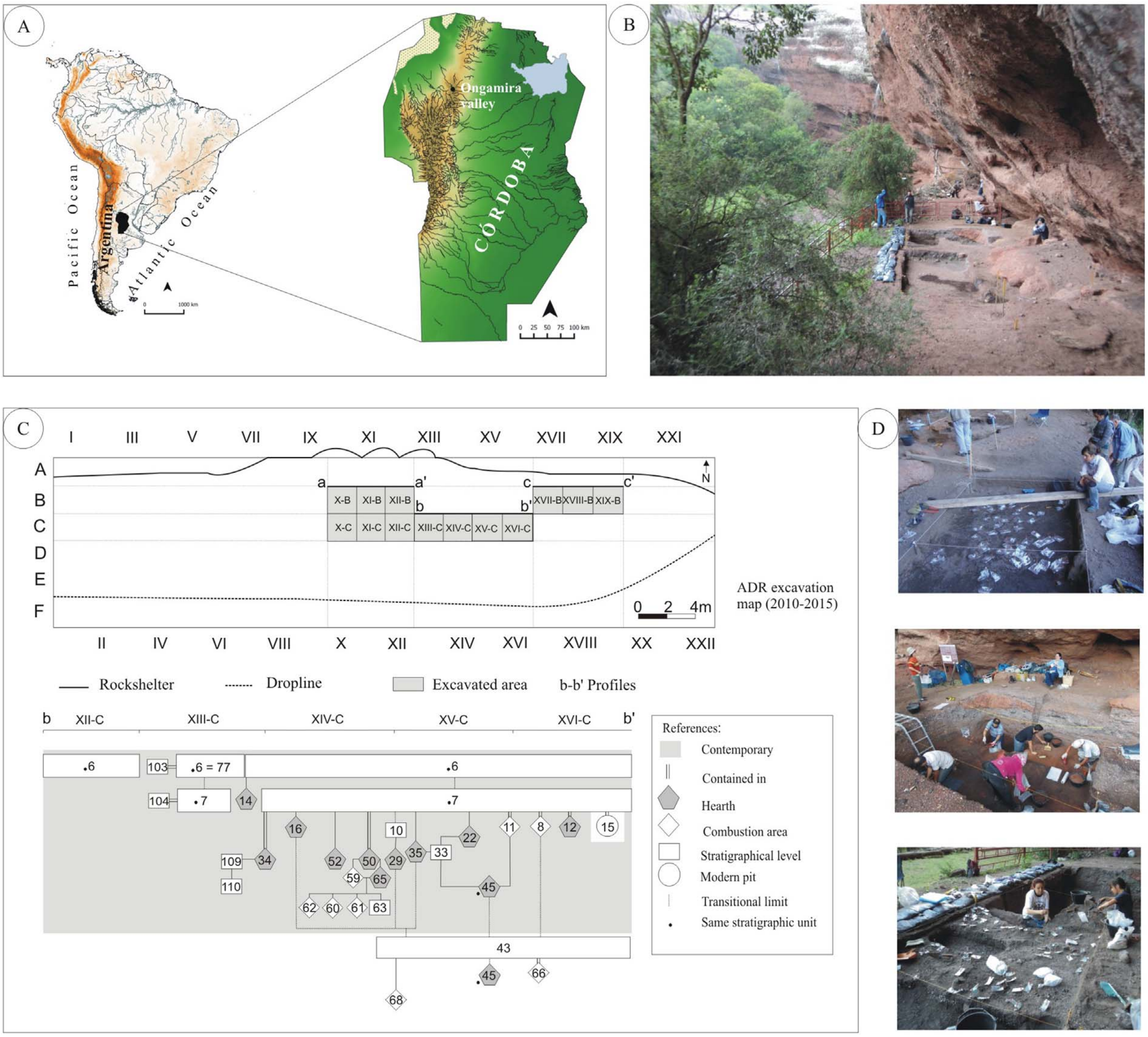

Fig. 1. A). Location of the study area. B). Deodoro Roca Rockshelter (ADR): general view of the site/general view of Deodoro Roca Rockshelter site. C). Scheme of stratigraphic excavations. Provenience of the archaeological samples (tools and bones) located in a Harris Matrix with the interpretations of the sequence of the stratigraphic units of ADR. D). Excavation process at the site.

Table 1

Radiocarbon dates from the excavations of ADR. From Units 7 and associated, and 43 are the tools and bones studied in this work. Calibrated with OxCal v4.2 Bronk Ramsey (2009); r: 5; SHCal13 southern hemisphere atmospheric curve (Hogg et al., 2013).

Lab. I.D.	^{14}C date (BP)	Calibrated age (cal BP) 1 sigma	Calibrated age (cal BP) 2 sigma	d^{13}C$_{PDB}$ (‰)	Square	Stratigraphic unit	Material
YU-2293	2942 ± 25	3201–3191; 3162–3068	3210–3002	− 26.77 ± 0.5	XIII-C	50	Charcoal
YU-2291	2944 ± 24	3075–2967	3159–2950	− 26.09 ± 0.43	XIV-C	7	Charcoal
YU-2290	2952 ± 21	3138–3130; 3107–3095; 3078–2991	3158–2959	− 25.72 ± 0.3	XIV-C	34	Charcoal
MTC-15144	3043 ± 41	3319–3310; 3245–3138; 3129–3107; 3095–3078	3345–3056; 3051–3030; 3014–3007	− 27.18 ± 0.3	XIV-C	65	Charcoal
YU-2292	3620 ± 27	3922–3835	3979–3823; 3792–3765; 3748–3728	− 24.75 ± 0.8	XVI-C	43	Charcoal

Alero Deodoro Roca, a hunter-gatherer multicomponent archaeological site dated between ca. 5000 and 2000 years BP (Cattáneo et al., 2013; Cattáneo and Izeta, 2016a,b) and located in the Southern Pampean Hills in Argentina.

This type of artifact has been traditionally characterized as a splitting tool used in different kinds of materials, specially wood (e.g. Ranere, 1975). In addition, in some cases the production methods of wedges were studied in relation to bone, antler and wood wedging (e.g. McPherson Smith, 2004). Also a discussion on this topic is available in e.g. Shott, 1989, Leblanc, 1992, and cited bibliography, and the association between wedges and bone working was questioned. This situation challenged us to discriminate the potential use of this particular tool for working different materials through a multiproxy approach, including an experimental program. Especially we were interested in exploring the use of the small wedges in materials such as *Lama guanicoe* ("guanaco") phalanges. This bone element was recovered from different stratigraphic units and found split in longitudinal halves. We understand this situation to be a practice directed towards two possible scenarios. The first, is obtaining raw material to produce bone artifacts that apparently occurred under different occupations in the site during the Late Holocene (Menghin and González, 1954; Costa, 2015). The second, related to the splitting as a result from bone marrow extraction

Table 2
Archaeological specimens of Camelidae (*Lama guanicoe*) presenting type of fractures recovered form SU 7 and 43.

Code	SU	Taxon	Element	Specimen age	Fracture	Breakage state	N
424	7	*Lama guanicoe*	First phalanx	Adult	Longitudinal	Fresh	2
502	7	*Lama guanicoe*	First phalanx	Unidentified	Longitudinal	Fresh	1
1035	7	*Lama guanicoe*	First phalanx	Unidentified	Longitudinal	Fresh	1
1554	7	*Lama guanicoe*	First phalanx	Juvenile	Longitudinal	Fresh	1
3308	7	*Lama guanicoe*	First phalanx	Unidentified	Longitudinal	Fresh	1
3383	7	*Lama guanicoe*	First phalanx	Unidentified	Longitudinal	Fresh	1
3633	7	*Lama guanicoe*	First phalanx	Unidentified	Longitudinal	Fresh	1
441	60	*Lama guanicoe*	First phalanx	Adult	Longitudinal	Fresh	1
1313	60	*Lama guanicoe*	First phalanx	Adult	Longitudinal	Fresh	1
1537	61	*Lama guanicoe*	First phalanx	Adult	Longitudinal	Fresh	1
1551	61	*Lama guanicoe*	First phalanx	Unidentified	Longitudinal	Fresh	1
445	43	*Lama guanicoe*	First phalanx	Juvenile	Longitudinal	Fresh	1
846	43	*Lama guanicoe*	First phalanx	Juvenile	Longitudinal	Fresh	1
1263	43	*Lama guanicoe*	Metatarsal	Juvenile	Longitudinal	Fresh	1
1319	43	*Lama guanicoe*	First phalanx	Adult	Transversal	Fresh	1
1361	43	*Lama guanicoe*	First phalanx	Unidentified	Longitudinal	Fresh	1
1529	43	*Lama guanicoe*	First phalanx	Unidentified	Longitudinal	Fresh	1
1539	43	*Lama guanicoe*	First phalanx	Adult	Longitudinal	Fresh	1
1547	43	*Lama guanicoe*	First phalanx	Unidentified	Longitudinal	Fresh	1
1548	43	*Lama guanicoe*	First phalanx	Unidentified	Longitudinal	Fresh	1
3348	43	*Lama guanicoe*	First phalanx	Unidentified	Longitudinal	Fresh	1
3352	43	*Lama guanicoe*	First phalanx	Adult	Longitudinal	Fresh	1
1323	43	*Lama guanicoe*	Second phalanx	Juvenile	Longitudinal	Dry	1
1360	43	*Lama guanicoe*	Second phalanx	Adult	Longitudinal	Fresh	2
Total							26

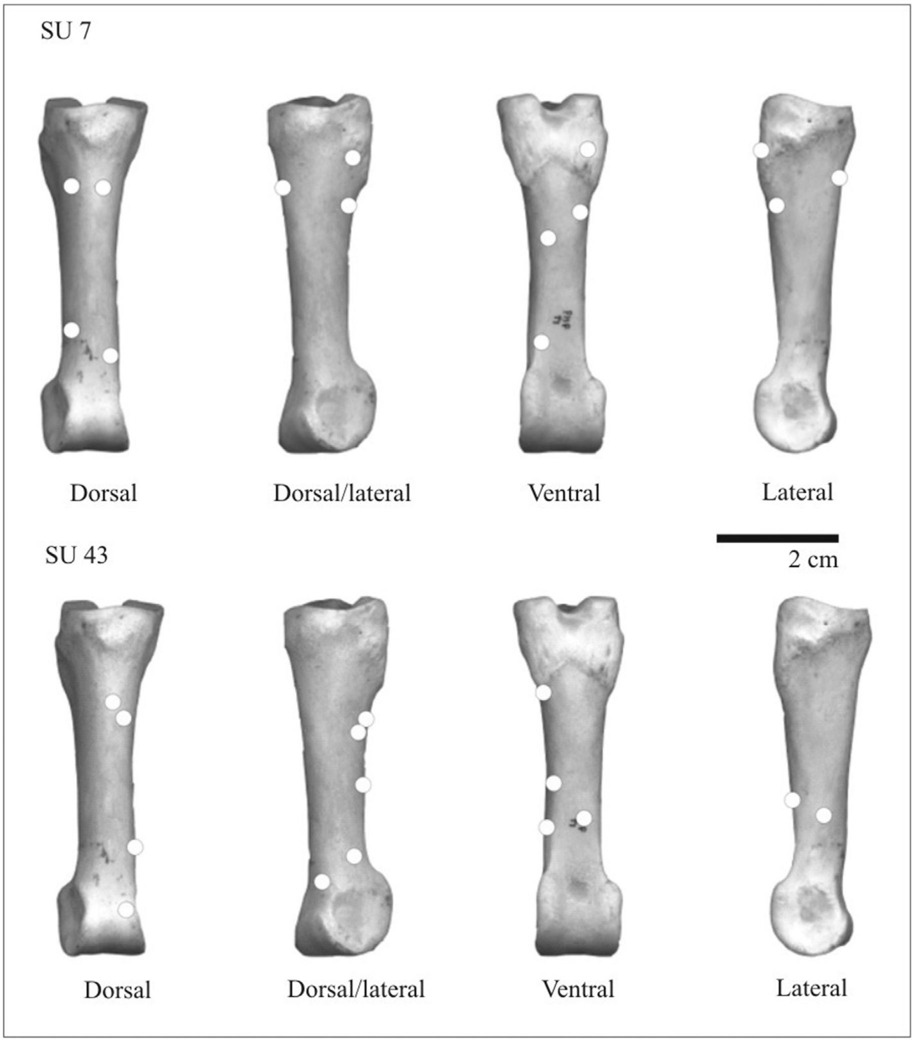

Fig. 2. ADR representations of the impact marks over phalanges of Camelidae presenting longitudinal fractures from SU 7 (and related ones) and 43.

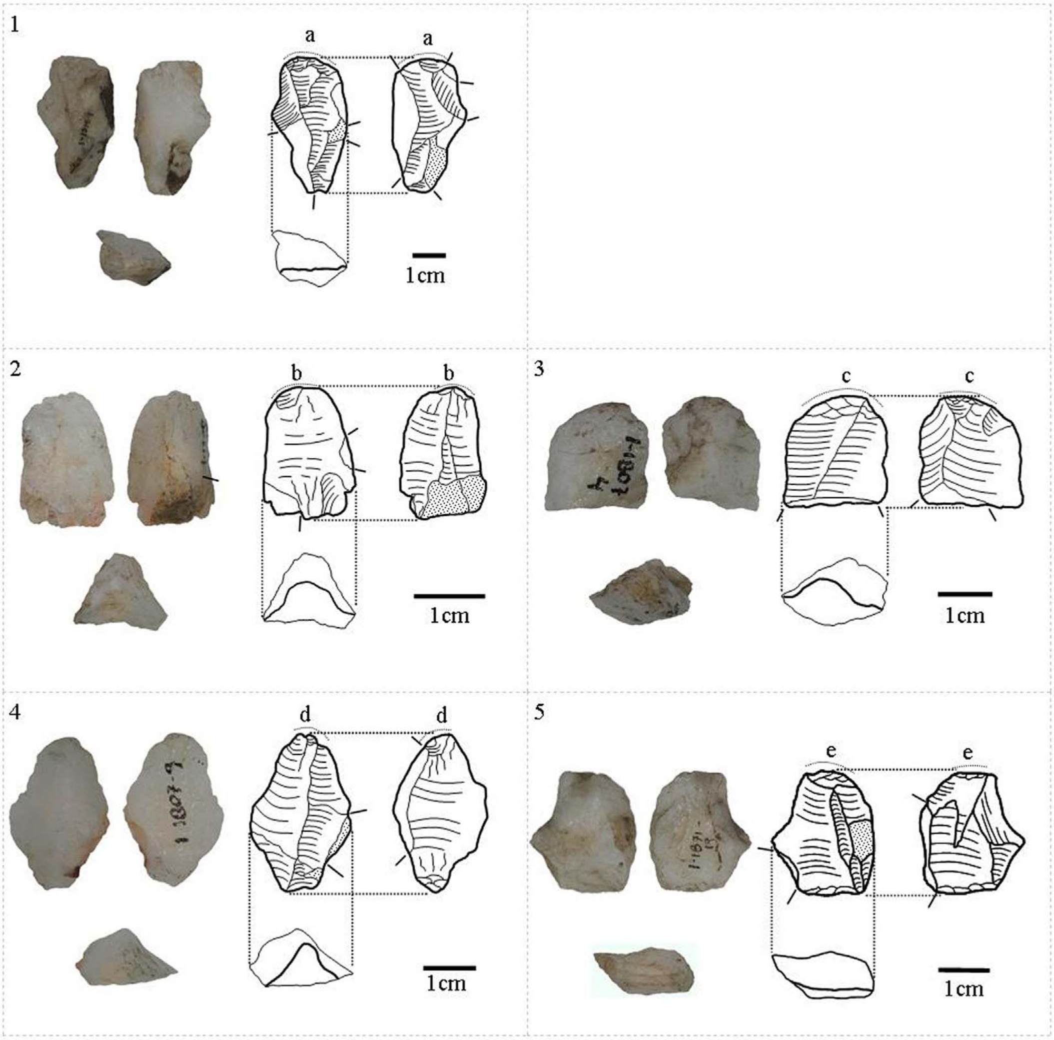

Fig. 3. Analyzed tools from stratigraphic units 7 (1) and 43 (2–5). a–e correspond to the sample edges with organic/inorganic residues.

Table 3
Description of the archaeological tools analyzed.

	Tool 1	Tool 2	Tool 3	Tool 4	Tool 5
Unit	7	43	43	43	43
Arch tool code	1-1515-1	1-1506-15	1-1807-4	1-1807-9	1-1871-19
Type of tool	Wedge	Wedge	Wedge (fractured)	Wedge	Wedge
Reduction technique	Bipolar	Bipolar	Bipolar?	Bipolar	Bipolar
Quantity of edges	2	2	1	2	2
Total length (mm)	38.1	20.7	–	28.3	22.5
Total width (mm)	21.1	13.5	18.4	18.3	16.7
Edges size (mm)	12.4 16.2	9.8 8.1	17.3	9.3 15.2	14.4 12.4
Edge angle (°)	26 40	34 35	35	35 36	35 34

techniques. Although the last is the most common interpretation in zooarchaeological studies, literature based on ethnographic, experimental and archaeological records tends to point to a blank acquisition strategy (e.g. de la Peña Alonso, 2011; Hays and Lucas, 2007; Leblanc, 1992).

In order to elucidate the probable relationship between people, small wedges and “guanaco” phalanges, we used micro-wear studies along with FT-IR analysis of residues recovered on the active edge of the tools. Also, some experiments were made with wedges and fresh and dry camelid bones and wood.

2. Site and sample description

Alero Deodoro Roca (ADR) is an archaeological site studied by the authors through an archaeological project that centers its research on Ongamira valley and its surrounding areas (Fig. 1A) (Cattáneo and Izeta, 2016a). ADR presents a large rockshelter of more than one hundred meters from one end to the other, with an average height of ten meters (Fig. 1B). It shows an amphitheater shape with a semi-permanent cascade in its center, which splits the large wall in two sectors: one facing west (Sector A), the other facing south (Sector B) (Zárate, 2016). Since the beginning of the project (2010), 83 m^3 have been excavated, registering the provenience of objects with an EDM which has allowed a precise digital reconstruction of the site (Fig. 1C, D). Within a depth of less than a meter at the center of Sector B, we registered nineteen combustion areas, more than twelve thousand gastropod shells, five thousand charcoal fragments, seventeen thousand animal bone fragments and more than ten thousand lithic remains (Cattáneo and Izeta, 2016b).

The site has a chronological sequence between 7000 and 1900 years BP. We have recognize 120 stratigraphic units (SU), following Harris Matrix's methodology (Fig. 1 represents the SU only discussed in this paper) and according to radiocarbon dates, some of

Table 4
Plants studied by FTIR from archaeological and comparative samples.

Sample n°	Sample type	Sample ID	Taxa
1	Archaeological charcoal, SU43	627-1	*Geoffroea decorticans* (Gillies ex Hook. & Arn.) Burkat
2	Dry wood, reference collection	1-4-8-R1	*Prosopis nigra* (Griseb.) Hieron.
3	Charcoal, reference collection	1-4-8-C1	*Prosopis nigra* (Griseb.) Hieron.
4	Charcoal, reference collection	2-5-5360-C	*Geoffroea decorticans* (Gillies ex Hook. & Arn.) Burkat
5	Dry wood, reference collection	1-6-4-T1	*Acacia caven* Molina
6	Dry wood, reference collection	2-5-356-R	*Cercidium praecox* (Ruiz & Pav. Ex Hook.) Harms
7	Fresh wood, reference collection	2-5-6124	*Celtis tala* (Gillies ex Planch.)
8	Fresh wood, reference collection	2-5-22613	*Zanthoxylum coco* (Gillies ex Hook. f. & Arn.)
9	Fresh wood, reference collection	2-5-4434	*Acacia caven* Molina

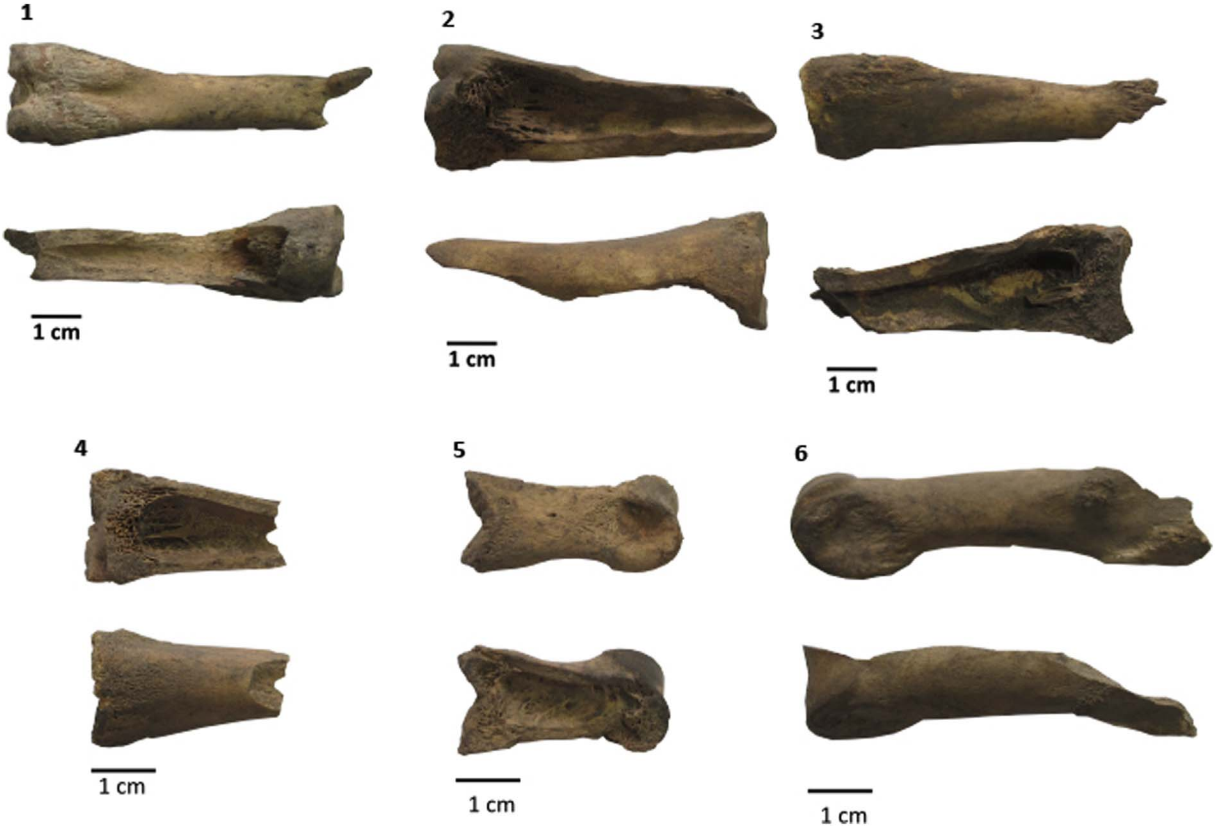

Fig. 4. Examples of the types of fractures on first phalanges of *Camelidae* from SU7 and SU43.

Table 5
Identification of archaeological bones characterized by FTIR analysis.

Sample	1	2	3	4
Element	First phalanx	First phalanx	Metatarsus	First phalanx
Weathering[a]	1	1	1	1
Thermoalteration[b]	1	0	0	1
Code	M. 1547	M. 502	M. 1263	M. 1035
SU	43	7	43	7

[a] Sensu Todd (1987).
[b] Sensu Nicholson (1993); 0 no macroscopic signs of thermoalteration (color = -yellow), 1 termoaltered (color = brown-red, temperature ≤ 200 °C).

those are penecontemporaneous with fourteen structured hearts (Table 1) (Izeta et al., 2016).

Anthracological studies were made in the structured hearths mentioned above, where we described 16 different plant species from the archaeological samples recovered. In order to study the possibility of manufacturing and using wood-tools from the past, and processing food (Robledo, 2016:173), we selected different types of woody plants, such as *Prosopis* sp., *Geoffroea* sp., *Acacia* sp. and *Cercidium* sp. (see Table 4). Also we use some fresh and dry branches for the experimental work.

Regarding the bone processing practices identified on ADR, the presence in the site of dulled points made from guanaco phalanges is locally known (Menghin and González, 1954: 245–246). They were recovered during the excavations that took place at ADR during the 1940s and 1950s and have been apparently produced through the sawing of the proximal epiphysis of the first camelid phalanges (González, 1943:153). Nevertheless, during recent excavations on the site few instruments have been recovered, none of this type and most of them retrieved from the back dirt filling of the historic excavations (Costa, 2015).

Thus, it is important to highlight the recurrent longitudinal fractures on guanaco first phalanxes, showing in 61% of the cases fractured phalanges in occupations linked to dates around 3600 cal BP and 50% in occupations from around 3000 cal BP. From 275 first phalanges of *Lama guanicoe*, 125 were recovered from the context dated around 3600 cal BP and 150 from 3000 cal BP (Costa, 2015).

Table 2 presents some of the bones recovered at ADR which, apart from being fractured, as described above, show impact marks (some of those represented in Fig. 2).

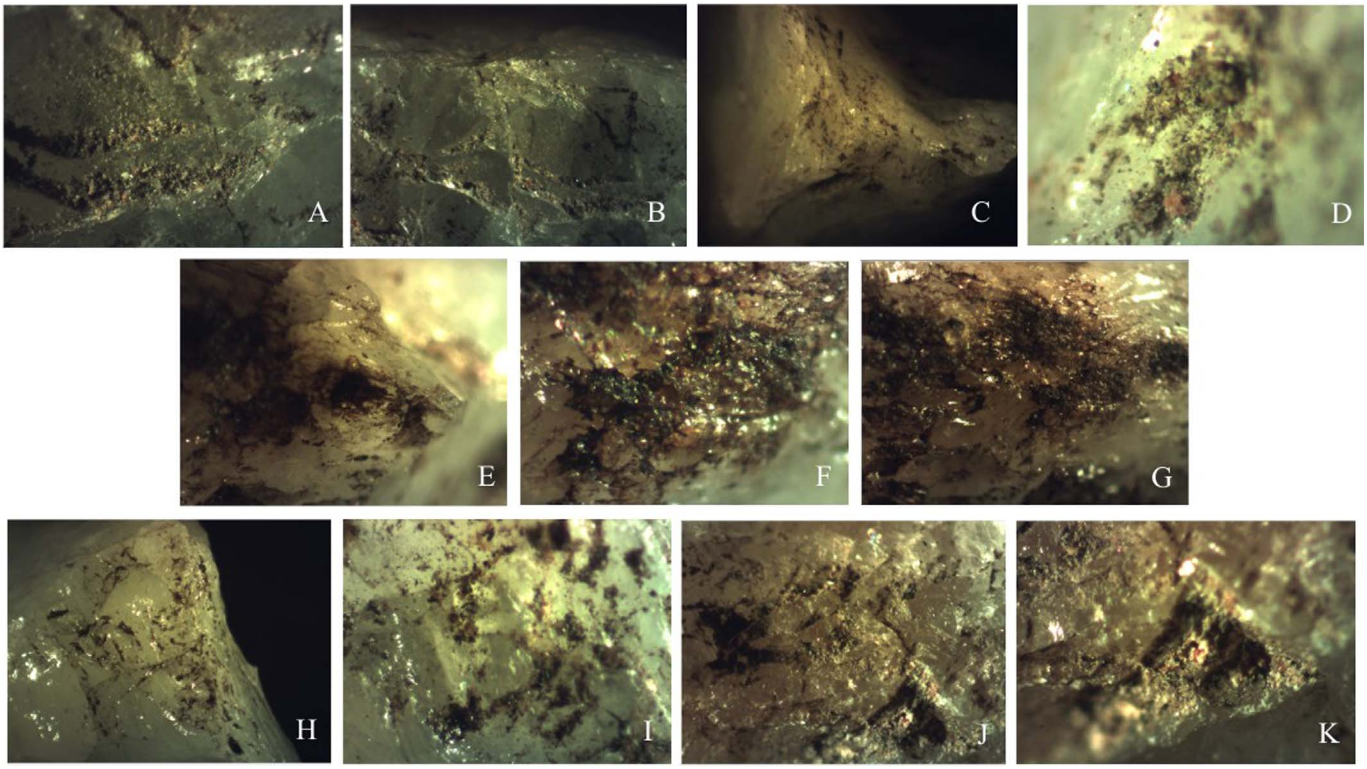

Fig. 5.1. Examples of photographs of residues under a Motic stereomicroscope and camera and prior to any further analysis: A) Tool 1, 20 ×; B) Tool 1,10 ×; C) Tool 2, 5 ×; D) Tool 2, 50 ×; E) Tool 3, 20 ×; F) Tool 3, 50 ×; G) Tool 3, 20 ×; H) Tool 4, 5 ×; I) Tool 4, 50 ×; J) Tool 5, 20 ×; K) Tool 5, 30 ×.

Some artiodactyls, like cervids such as *Mazama gouazoubira* and *Ozotoceros bezoarticus*, including metapodial remains of guanacos (see Table 2), also showed impact marks ($N = 72$) and some of these revealed the same characteristic longitudinal fracture that we associate with the wedges analyzed here ($N = 18$, Costa, 2015). Hence, we decided to include a *guanaco* metatarsal fragment in our analysis (Table 2), and also in our experimentations. On the other hand, denser mammal and artiodactyl bones (such as femur or humerus) displayed impact marks ($N = 249$) like the less dense metapodials and phalanxes, even though we could not associate these marks with the wedges presented here, due to their size.

3. Methodology

3.1. Microwear analysis

Prior to any further analysis, lithic tools were first sampled for presence of residue using a stereomicroscope, since it is crucial to avoid excessive washing and use of alcohol, both of which can potentially alter the composition or even remove residue.

Residue samples were collected by softly removing the adherent substances with a metal scalpel and then introduced into a sterile Eppendorf container to avoid further contamination. The surface was then cleaned with soapy water and acetone. Traces of microwear use traces were analyzed through comparison with an experimental reference collection of tools made from quartz and used for 5, 15, 30 and 60 min on different types of materials: fresh and dry bone, hard and soft wood, fresh and dry leather, and different types of plants (Pautassi, 2014). After that, the experimental traces were compared with those observed on archaeological tools according to van den Dries and Van Gijn (1997).

A metallographic (incident light) microscope using low and high magnifications (Motic, magnifications 5 × to 400 ×) was employed to register surface damage and tool use. We followed the principles set out by Tringham et al. (1974) and elaborated further by Odell (1977) and others (e.g. Unrath et al., 1986; Mansur-Franchomme, 1986; Evans and Donahue, 2005; Evershed, 2008; Evans, 2014) especially through blind tests. The tools were additionally analyzed with a metallographic microscope (Motic, magnifications 100 × to 500 ×), using bright field illumination as described by Keeley (1980). After that, traces were classified according to different types of attributes as in Hurcombe (1988), Cattáneo and Fernández Ordóñez (2008) and Babot et al. (2013). Laser images of the traces were captured with an Olympus LEXT Laser confocal microscope, which allowed us to observe tridimensional regions and study the similarities and differences between the surface of the tools according to Plisson and Lompré (2008) suggestions.

3.2. FT-IR analysis

A variety of archaeological and fresh samples have been examined using FT-IR spectroscopy. These include residues from the active edges of lithic tools and all the surrounded organic materials recovered during stratigraphic excavations (sediments from SU7 and SU43), bones (dry and thermoaltered), *Lama glama* (“llama”) meat, wood (different species), and charcoal (also some fresh samples from a reference collection (Robledo, 2016)).

As said above some residues were obtained through removing softly the adherent substances while some other residues samples were directly characterized through FT-IR analysis without removing the residue from the active edge.

FT-IR spectra were obtained using a Thermo Scientific Nicolet iN10 Infrared Microscope with cooled detector MCT-LN$_2$ operating between 650 and 4000 cm^{-1} with a resolution of 4 cm^{-1}. Small quantities of each sample were supported on KBr discs; MCT allows collection of samples as small as 10 μm or less.

Because the detector MCT-LN2 operates between 650 and 4000 cm^{-1}, it is impossible to observe bands under 600 cm^{-1}, however, typical bands of hydroxyapatite, could be observed overlapping carbonate vibrations.

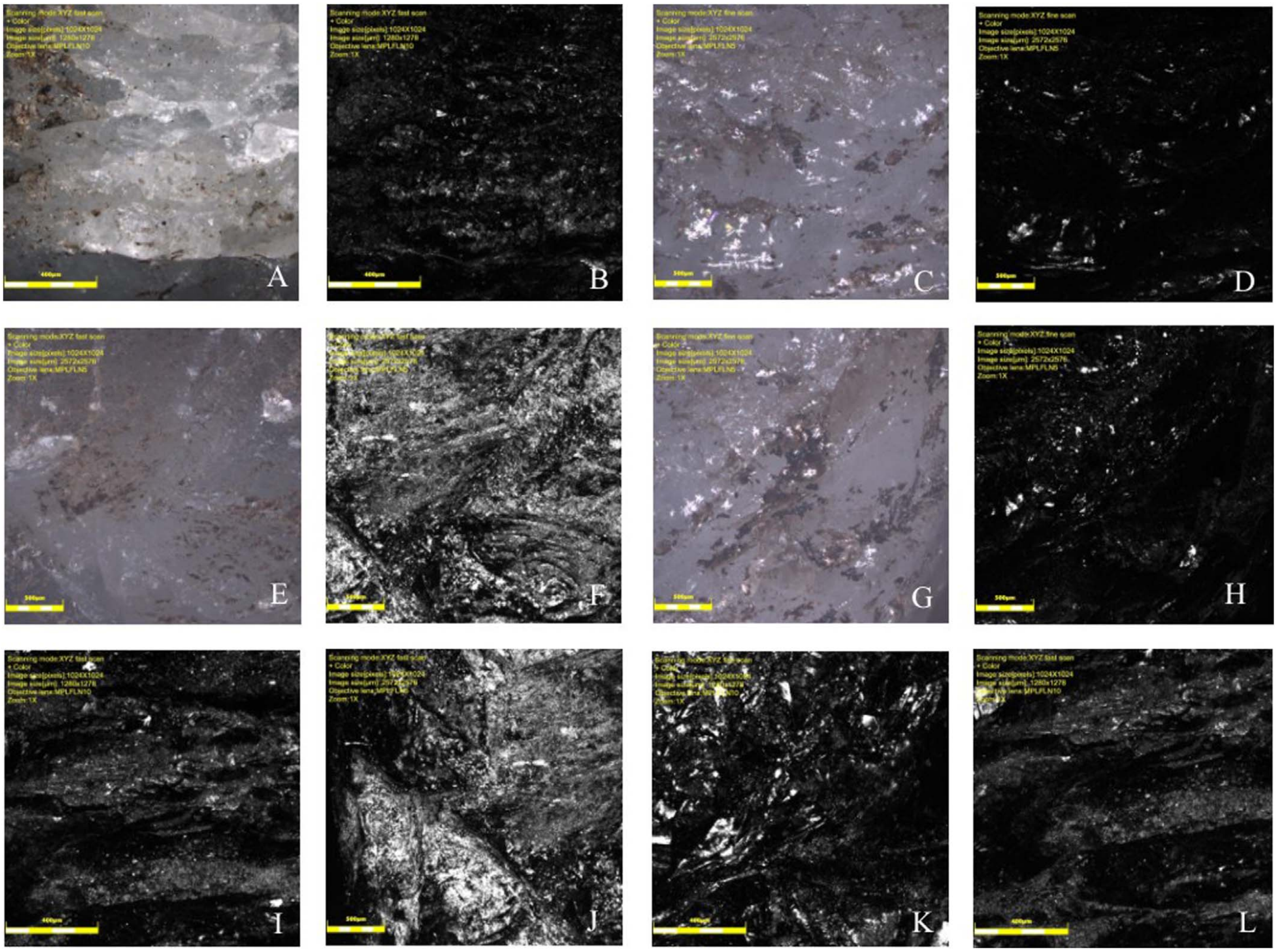

Fig. 5.2. Examples of images of residues and edge damage under LEXT confocal laser microscopy at 216 × of magnification: A) Tool 1, edge 1, color image of damage edge; B) Tool 1, edge 1, laser image of the surface; C) Tool 2, edge 1, color image of damage edge; D) Tool 2, edge 1, laser image of the surface; E) Tool 3, color image of damage edge; F) Tool 3, edge 1, laser image of the surface; G) Tool 4, color image of damage edge; H) Tool 4, edge 1, laser image of the surface; I) Tool 5, edge 1, laser image of the surface; J) Tool 5, edge 1, laser image of the surface; K) Tool 5, edge 1, laser image of the surface; L) Tool 5, edge 1, laser image of the surface. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table 6
Results of microwear analysis of the archaeological micro wedges according microscopic wear variables from Hurcombe, 1988 (between 100 × and 216 ×).

Edge-wear pattern	Tool 1	Tool 2	Tool 3	Tool 4	Tool 5
Distinctness of the altered surface from the unaltered	Very distinct	Very distinct	Distinct	Distinct	Very distinct
Edge roundedness of the polished area near the tool edge	None	None	None	None	None
Striation variables (width)	More than one width class present	More than one width class present	–	More than one width class present	–
Presence of microscopic flaking or crushing	Abundant	Abundant	Abundant	Abundant	Abundant
Extent of the attrition along the edge	Pronounced.	Pronounced.	Severe	Pronounced.	Pronounced.

4. Materials analyzed

4.1. Archaeological tools

The organization of the technology in ADR, relies on a particular raw material: the quartz. This rock is local, abundant, and most of the tools were made on it throughout the occupational sequence (between ca. 1900 cal BP and 7000 cal BP). In this site diverse groups of tools were described according to different occupation levels. In particular we establish the presence of several small wedges, in some cases related to the use of bipolar technique as the core reduction technique (Caminoa, 2016). Some of these wedges still contain macroscopic residues in some of their active edges, allowing us to pursue the investigations into the use of this type of tool through time in the region.

The samples selected comprised five tools from two different levels: one from SU7, radiocarbon dated in (YU-2291) 2944 ± 24 BP, and four from SU43 with a dating of (YU-2292) 3620 ± 27 BP. Although more wedges were recovered from these and other SU from ADR, they showed no residues for analysis (Fig. 3 and Table 3).

Table 7
Results of FTIR tool residues.

Tools				Peak assignments	Origin of peak
2	3	4	5		
3383	3372	3448	3383	Stretch O–H	Inorganic/ organic
2920	2917	2957	2971	Carbonate (CO_3^-) overtone/ combination	Inorganic
1994	1991	1999	1985		
1874	1868	1863	1863		
1795	1792	1778	1789	Carbonate (CO_3^-), C-O	
1519	1522	1465	1516	Carbonate (CO_3^-), asymmetric stretch	
823	817	840	772	Carbonate (CO_3^-), out plane vibration/SiO bend	
695	698	692	689	Carbonate (CO_3^-), stretch or in plane bend	
1200–1000				Si O–Si bend	Inorganic
2920	2917	2957	2971	Stretch C–H (alkane)	Organic
1795	1792	1778	1789	Stretch C=O (carbonyl group)	Organic
1681	1681	1724	1678		
1610	1610	1658	1613		
1200–1000 and 900–880				Stretch C–O and C=C–H	Organic

Table 8
Results of FTIR on sediments from ADR.

Sediments		Peak assignments	Origin of peak
1	2		
3468	3440	Stretch O–H	Inorganic/organic
		Carbonate (CO_3^-) overtone/combination// stretch C–H	Inorganic/organic
2513	2522	Carbonate (CO_3^-) overtone/combination	Inorganic
1800	1795	Carbonate (CO_3^-), C–O/stretch C=O (carbonyl group)	Inorganic/organic
1644	1640	Carbonate (CO_3^-), C–O/stretch C=O (carbonyl group)	Inorganic/organic
1445	1445	Stretch carbonate/stretch C-H	Inorganic/organic
1025	1025	Si–O stretch/stretch C–O	Inorganic/organic
877	874	Carbonate (CO_3^-), out plane vibration/SiO bend	Inorganic
722	718	Carbonate (CO_3^-), out plane vibration/SiO bend	Inorganic

4.2. Comparative samples analyzed by FT-IR

In order to eliminate the possibility of cross contamination from the matrix by residue analysis, we studied, via FT-IR, samples of organic material associated with the tools from SU7 and SU43. In addition, we analyzed, following the same technique, sediment samples in order to segregate their composition from the residues recovered from tool edges.

4.3. Sediments

The tools under study were recovered from two different units:

Stratigraphic Unit 7: Characterized by the presence of blackish sediments (Munsell's color 10YR/2/1) containing large amounts of entire terrestrial land snail shells (Izeta et al., 2014), mainly associated with fragmented camelid bones, dispersed charcoal fragments, and small combustion areas. The unit also contains red gravel, probably originated from the disaggregation of the bedrock. Developed through squares XIII-XVI-C, in some areas it presents the fragmentation of the land snail shells like in square XV. This stratigraphic unit contains other discrete units such as SU 8, 9, 11 and 12.

The radiocarbon dates locate the human occupations of this SU around 3000 cal BP (Table 1). Different hearths related to SU 7 with penecontemporaneous dating are SU 50, 34, and 65. The archaeological code for the sample studied in this work is ADR 306//5 4–10 UE7 XIV C and named as Sediment Sample 1.

Stratigraphic Unit 43: Characterized by the presence of brownish sediments (Munsell's color 5YR/2.5/2) containing large amounts of dispersed charcoal fragments and highly fragmented land snail shells. As in the previous stratigraphic unit, some gravel size particles from the bedrock are noticed. Ash layers (lens-shaped) associated with large amounts of animal fragmented bones and lithic material were described for the unit. Located through squares XIII-XVI-C and developed after a transitional limit immediately under SU 7. The code for sediment Sample 2 in this work is ADR 434//8-4-10 UE43 XVI C.

4.4. Woody plants

One of the characteristics of the units is the great abundance of charcoal. As described in Robledo (2016), the composition of the hearts varied in species in each stratigraphic unit, thus, samples of different species were analyzed for FT-IR. Examples of archaeological charcoal were recovered from combustion events (see Table 4). Samples of dry wood and charcoal from the reference collection were also studied considering the importance of these species in the manufacture of tools and food processing (Robledo, 2016:111).

4.5. Bones

According to the different conservation states of each SU, Camelidae bones presenting fractures (as in Fig. 4) were selected for FT-IR analysis. Burned and unburned archaeological samples and fresh bones were chemically characterized.

4.6. Meat

Considering the interpretations of the use of the rockshelter during both occupations (SU 7 and 43), Costa (2015) concluded that bones entered into the site in a fresh state and with soft tissues, and because of that a non-archaeological sample of Camelidae dry meat was analyzed in order to evaluate a possible FTIR result linked to this kind of organic element.

Table 9
FTIR results on bones samples.

Bones				Peak assignments	Origin of peak
1	2	3	4		
3330	3323	3385	3356	Stretch O–H	Inorganic (hidroxyapatite)/organic
1662	1658	1798 1645	1626	Carbonate (CO_3^-), C–O/stretch C=O (carbonyl group)	Inorganic/organic
1461	1483	1446	1446	Stretch carbonate/stretch C–H	Inorganic/organic
1020–1101	1013–1101	1016–1090	1027–1101	Stretch C–O/PO_4^{3-}	Organic/inorganic (hidroxyapatite)
878	876	878	876	Carbonate (CO_3^-), out plane vibration	Inorganic

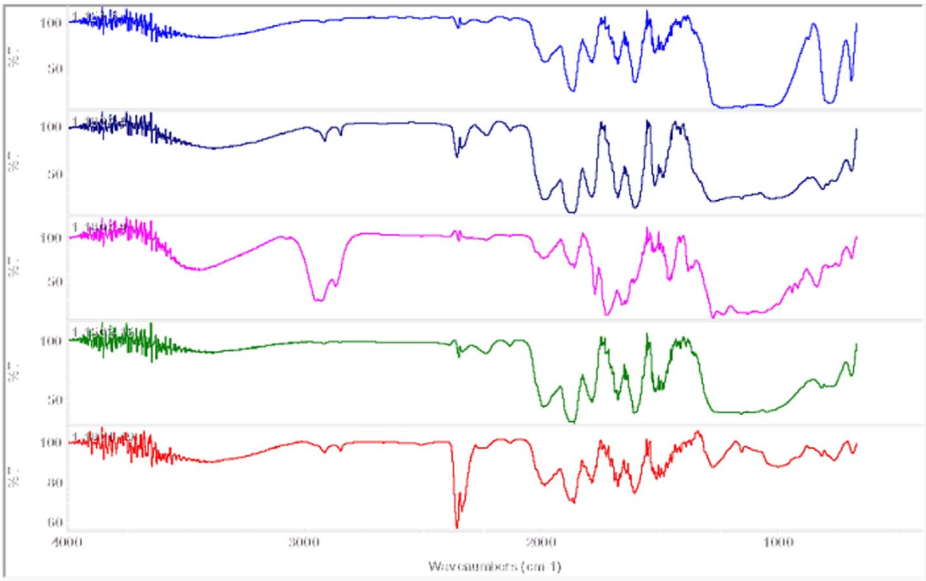

Fig. 6. Spectra of FTIR analysis of tool residues 1 to 5. (M. 1515-1; M. 1807-4; M. 1807-9; M. 1506-1; M. 1871-19).

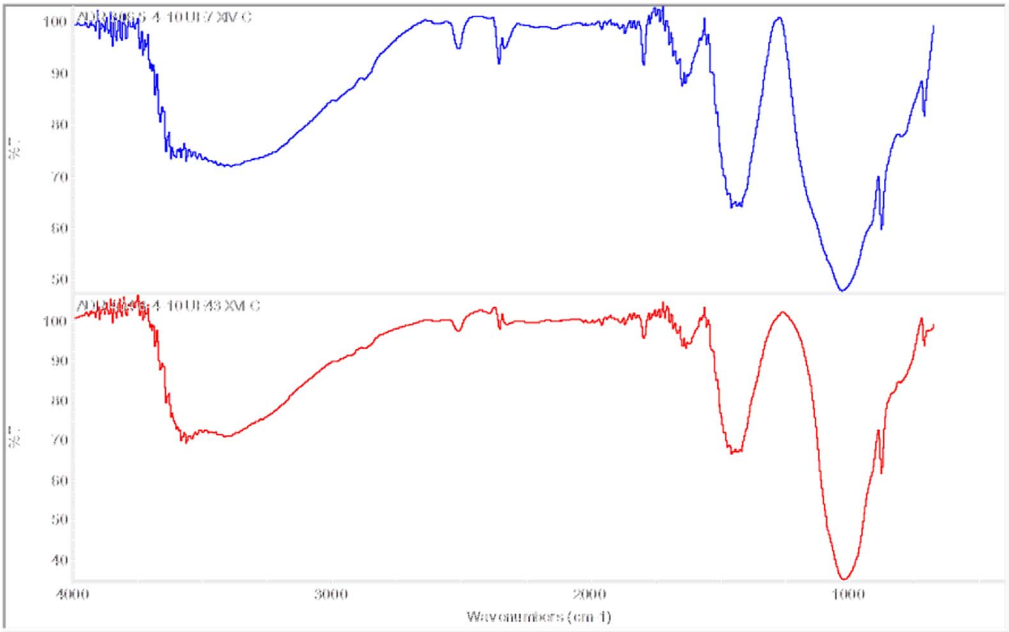

Fig. 7. Spectra of FTIR on sediments from SU 7 and 43 ADR site.

5. Results

5.1. Microwear trace analysis

As mentioned above, the sampled tools were washed with a solution of warm water and soap. After that, the active edges were cleaned with acetone using cotton swabs to remove the residues prior to observation under reflective light and laser microscopy. In each case a use-wear (functional) analysis was conducted with the tools, primarily based on various microscopic features. Once the technical and natural wear features were eliminated, we registered patterns of micro-scars, striations and polishes in different magnifications. We present the variables identified in Table 5 and Figs. 5.1 and 5.2.

5.2. FT-IR analysis

The five tools were sampled for FT-IR analysis. In most cases the tool was located at the stage of the microscope and we focused on the active edge with residues and proceeded to apply the Fourier Transform Infrared spectroscopy analysis. Peak frequency is expressed in cm^{-1}.

5.3. Archaeological tools (1 to 5)

A broad OH peak was present in all samples around 3380–3440 cm^{-1}, indicating the presence of H-bonded OH. This distinctive shape of the OH region of the spectra confirms the presence of hydration water of inorganic salts or calcium hydroxide. Carbonate overtones and combinations were in similar position; these bands can be seen around 2920, 1990 and 1850 cm^{-1}. The asymmetric stretching appears around 1515–1560 cm^{-1} while in- and out-of-plane vibrations appear at 780–800 $cm^{-1}$and 690 cm^{-1}, respectively. Due to the position of the out-of-plane vibration, and the presence of a broad signal between 1000 and 1200, it is suggested that these peaks occur from overlapping of Si—O bending. In addition, all samples show a number of characteristic peaks which resemble the spectra of organic compounds, including the distinctive C—H peaks around 2900 cm^{-1}, at 1613–1680 cm^{-1} corresponding to C=O bond, stretching vibration corresponding to C—O bond around 1000–1200 cm^{-1} overlapping

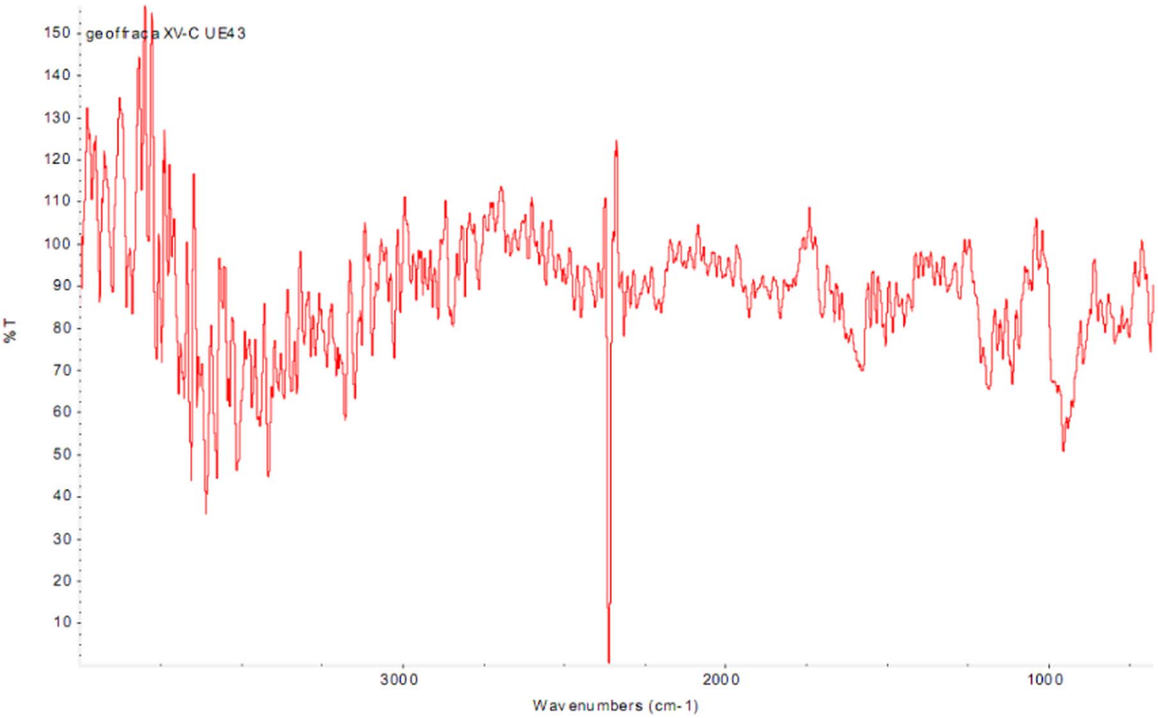

Fig. 8. Example of FTIR of *Geoffroea decorticans*, sample n° 1.

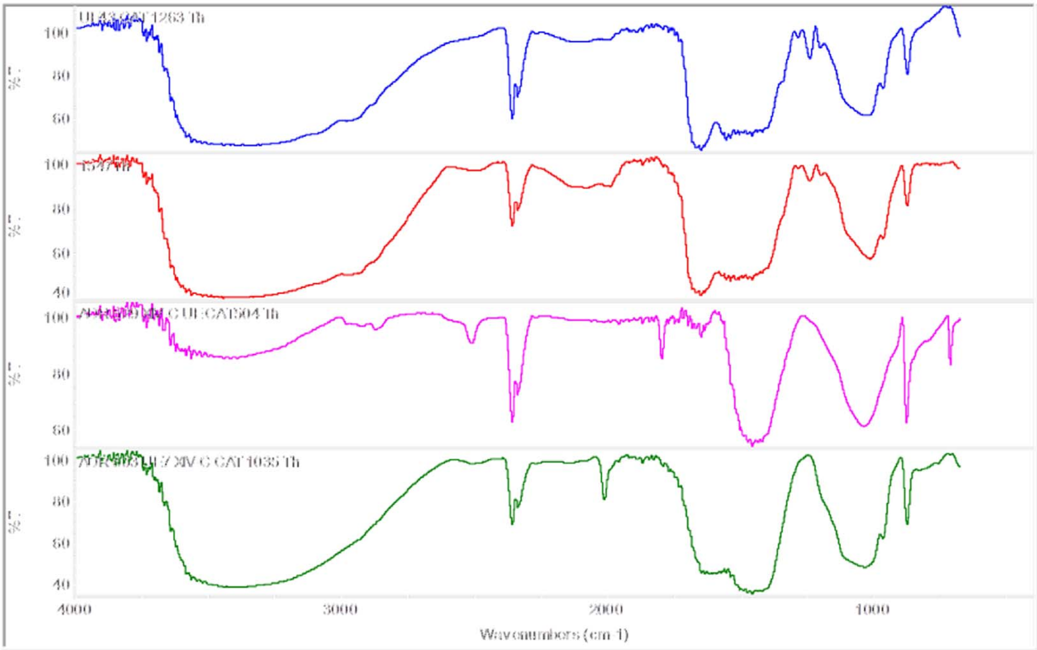

Fig. 9. Spectra of FTIR analysis on bones fragments 1 to 4.

Si—O bending. The presence of carbonyl signal suggests a ketone or similar group as part of a structure or the degradation product from protein. Particularly, M. 1807-4 spectrum shows weak peaks at 928 and 948 cm^{-1} corresponding to C═C stretching and bending modes. These structural characteristics are found, for example, in terpenes (Table 7).

5.4. Sediments

The different bands of the spectra suggest the presence of carbonate and silica. The broad band around 3400 cm^{-1} corresponds to water or calcium hydroxide, the overtone and combination band of carbonate appears at 2522/2513 cm^{-1}. The peaks at 1445 and 1025 cm^{-1} are strong and correspond to overlapping of stretching of carbonate and silica. However, in this region, we can also see C—H vibration of organic compounds. The signal at 871/877 cm^{-1} could evidence the presence of carbonate.

5.5. Woody plants

The preparation of these samples for spectroscopic analysis was difficult since the physical characteristics and the spectra were of low resolution. However, it was possible to observe the presence of organic compounds and their signals appearing around 1600, 1500, 1100 and 950 cm^{-1}. All peaks could be assigned to C═O, C—O, C—H, C═C—H

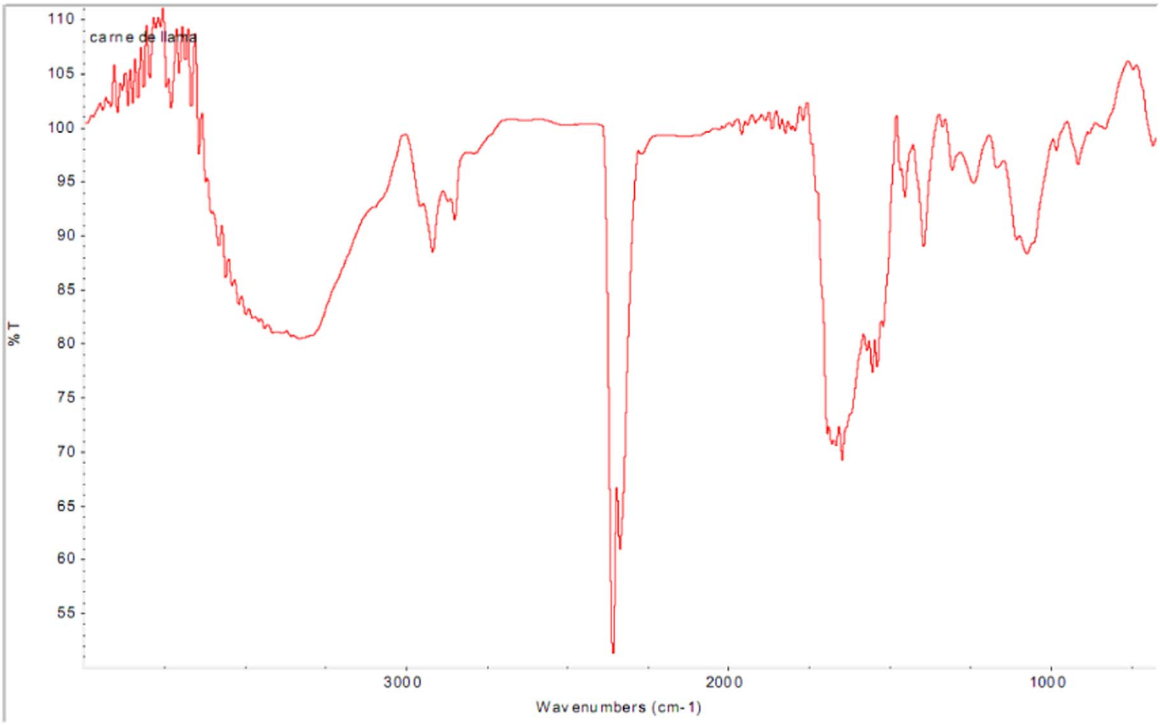

Fig. 10. Spectra of FTIR on Camelidae fresh meat.

corresponding to different organic compounds.

The Fig. 8 shows FT-IR spectra of wood reference material. The resolution of spectra is low; it was very difficult to register. However, it could observe characteristics bands corresponding to organic material about 1600, 1400 cm^{-1} and lower frequency.

5.6. *Bones*

The spectra show a mix of organic and inorganic compounds, although peak intensity varies. The band corresponding to OH vibrations is wide and overlaps with carbonate overtones and combination peaks. The presence of carbonate in these samples could be evidenced by the out-of-plane vibration of carbonate around 876 cm^{-1} and the signal around 1040 cm^{-1} corresponding to C—O stretching, indicating organic composition. The spectrum of the four samples shows around 1640 cm^{-1} overlapping the characteristic bands of carbonate and carbonyl. The signal at 1440 cm^{-1} could correspond to stretching carbonate or C—H bond of organic compounds.

Also, typical bands corresponding to hidroxyapatite characteristics of bones, such as OH vibrations about 3600–3500 cm^{-1} and PO43- vibrations about 1030–1090 cm^{-1} could appear overlapping with the bands already described.

5.7. *Dry meat*

The spectrum evidences the organic composition of the sample. Typical bands corresponding to stretching and bending bonds of organic compounds such as proteins, lipids and carbohydrates are observed. The band corresponding to OH vibrations is wide and overlaps with N—H, appearing around 3130 cm^{-1}. The signals between 2948 and 2846 cm^{-1} correspond to C—H stretching, evidencing the aliphatic chain of organic compounds. Around 1692–1533 cm^{-1}, the spectrum shows an overlap of the characteristic bands of stretching carbonyl, including band I of amide group of proteins and ester of proteins, lipids and oil acid with the bending (band II) N—H bond of the nitrogen compounds. Stretching C—O and C—N bands appear overlapped around 1454–1241 cm^{-1}. Less important bands corresponding to bending N—H can be seen between 979 and 820 cm^{-1}.

6. Discussion

In relation to morphology, microwear use traces and residues, we observed a correspondence between distinctive traces of damage attributed to breakage of hard material and absence of polish (generally recognized because of scraping or cutting) as described in Table 6 and Figs. 5.1 and 5.2. Particularly the type of damage is consistent with the experimental results of breaking or splitting fresh and dry bones, specifically phalanges, other than bigger bones as metapodials which results in other type of traces (Fig. 11). In our experimental program (no developed here) we collect information about the use of wedges and the residues left after work. First, was observed that the use of soft hammers (made in hard wood as *Prosopis* sp.) to hit the wedges result in the same type of damage in platforms as the ones in the archaeological record, while the use of hard hammers result in the destruction of the platforms. Second, if we made a comparison between the micro damage found in the archaeological wedges (Fig. 5.2) and the experimental ones we observed the same type of damage when fresh and dry phalanges were split (Fig. 11: A, B and C; and Fig. 12A). This is not the case when attempting to break metapodials: the edge of the tools were severe damaged with crushing (Fig. 11: D, E and F) and the metapodials did not show any signs of breakage (Fig. 12B).

Evenmore, considering the archaeological wedges sizes and the high quantity of half split phalanges in the studied archaeological layers we hypothesized the advantages of such endeavor. On one hand, marrow extraction could be one of the hypotheses, especially considering that people were extracting marrow from other bones, usually bigger in size (Costa, 2015). Though, in those bigger bones a different pattern of breakage is showed (probably due to very different bone architecture). Also, previous work yielded that camelid phalanges have only 1,4% of marrow from a total gross weight of ~95 g (see De Nigris and Mengoni Goñalons, 2005: Table 2). This means that phalanges exhibit one of the lowest marrow values from the camelid skeleton. On the other hand, a second hypothesis is based on splittering this particular dense bone for using them as blanks for further tool manufacture.

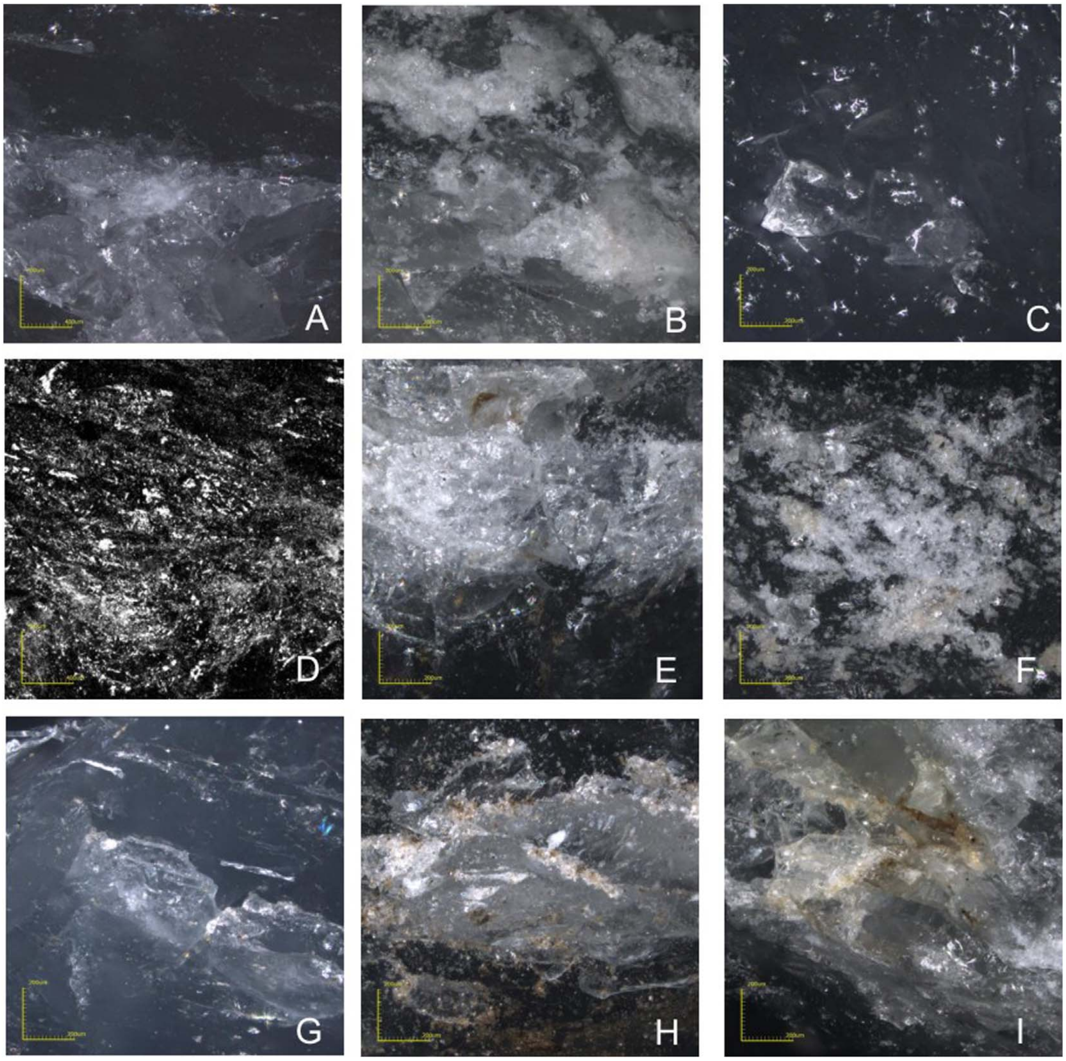

Fig. 11. Microwear traces over actives edges of experimental quartz small wedges, registered using Olympus LEXT (at 216 ×). A) Experimental case n° 3029, edge used to split a dry camelid first phalange. B) and C) Experimental cases n° 3139 and n° 3141, edges used to split a fresh camelid first phalange. D) and E) Experimental case n° 3031, edge used to split a fresh camelid metapodial. F) Experimental case n° 3028, edge used to split a dry camelid metapodial. G) Experimental case n° 3136, edge used to split a fresh branch of *Zanthoxylum coco*. H) Experimental case n° 3132, edge used to split a dry branch of *Celtis tala*. I) Experimental case n° 3133, edge used to split a fresh branch of *Celtis tala*.

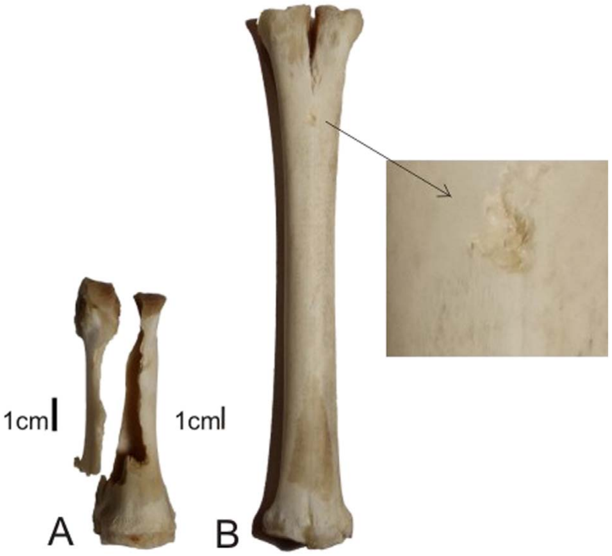

Fig. 12. Experimental cases of breakage pattern in camelid bones. A) Fresh first phalange broken with a quartz small wedge using a wood hammer. B) Metapodial with marks produced by a small quartz wedge using a wood hammer.

Based on the above experimental program mentioned to understand the relationship between the marks observed on the archaeological bones and the use of the small wedges, several fresh and dry first phalanges and metacarpals from modern *Lama glama* (llama) were split using modern quartz wedges. Although, the operators lack experience in breaking bones with wedges (moreover this was their first time doing it) they rapidly achieve to obtain first phalanges halves product of longitudinal breakage, similar to the archaeological ones (Fig. 12A and B). The metacarpals used in this experiment behave in a different manner. The small wedges did not achieve the goal of breaking the bones because the active edge collapsed every time. We look for volume density for first phalanges and metacarpals as a probable factor in the differential breakage and we realized they have similar values in the diagnostic zones used here to break the bones (Stahl, 1999). Nevertheless, it is worth to consider that first phalange scan site P12 it is ranked within the densest scan sites as stated by Stahl (1999). Maybe because of this bone property, a tool like the small wedge becomes efficient to break the phalanges.

When using experimental wedges to break woody vegetable material there were two situations, on one hand, the fresh and soft material (e.g. *Zanthoxylum coco*, *Acacia caven*) did not generate damages similar to those of archaeological cases, but instead the surface of the active edge did not practically show any modification, especially the crushing type (Fig. 11G). In the case of intermediate woods such as *Celtis tala* or *Geoffroea decorticans* the damages are more similar (Fig. 11H and I) but the task usually left adhered residues that were very difficult to eliminate and in our case should have been able to be identified in the FTIR analysis. In experimental cases with harder woods (*Prosopis* sp.) the edges broke, proving not to be suitable for this task.

FT-IR is a useful technique for screening suspected samples. The spectra of different samples showed the presence of a mix of organic and inorganic compounds (Tables 7 to 9). Tool samples showed distinct carbonyl peaks in their spectra corresponding to organic residues from protein or degradation products (Table 7). Signal characteristics of C—H and C═C—H bonds assigned to saturated and unsaturated chain of organic compounds were also observed in spectra of tools (Table 7 and Fig. 6). Particularly, bands from organic residues occurring in the fingerprint region were not likely to be assigned with certainty.

Moreover, in analyzing meat, wood, and charcoal samples, FT-IR spectra were clearly different (Tables 8,9 and Figs. 6–10). These spectra show signals corresponding exclusively to organic compounds.

Close inspection of the FT-IR spectra in Fig. 6 (residues on tools) and Fig. 9 (bones fragments) show intriguing similitude. These samples show similar bands pattern corresponding to the inorganic (carbonate and hidroxyapatite) compounds.

In sum, the actualistic samples gave us some chemical characterization that allows segregating them. Here, the comparison between these characteristics and those registered in the archaeological samples shows the tendency to use bony material by small wedges.

7. Final remarks

As mentioned before, our interest centered on gaining insights into the relationship between things and humans. Along this paper, we used several methodologies and techniques to prove that a specific tool, such as the small wedge, was used to interact between people and things. Indeed, we could observe and interpret, in the biography of the objects, how they relate to each other offering a glimpse into the continuum of the past technological system in two different moments during occupation of ADR.

The morphological identification of the small wedge, its functional assessment made through a traceological analysis and the results from chemical fingerprint analysis have allowed us to get close to the activities of past people from a data-proven approach.

Analytical studies based on ethnoarchaeological data, microwear studies under high and low power microscopy combined with FT-IR have allowed a multi-dimensional approach. Accordingly, we believe that residue analysis has contributed significantly in this direction. In addition, the relatively low cost of FT-IR and the quick method of sample preparation and analysis have turned this into an attractive method for preliminary identification of archaeological samples.

In sum, all the data presented here have allowed us to interpret that small wedges were used as a controlled way to split the phalanges to use them for marrow extraction or as raw material for other purposes. This action seems to be persistent through both occupations (3000 and 3600 BP) at ADR.

Nevertheless, we still need to find out who produced and used this particular type of tool. In effect, we might need to explore the idea of females or children's use or production (Gero, 1991), especially if we consider morphological attributes such as:

- size of stone tools, and length and angle of cutting edge in terms of cutting mechanics and functional use.
- specific patterns of crushed surfaces, though we understand that we have to be careful about these attributes and patterns following Key (2016); and,
- small size registered in ADR tools.

As Hodder (2014) has claimed, there is still much to be done to understand the different paths by which we have developed as humans, involved in our varied ways with things.

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