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Mid-Holocene geochronology, palaeoenvironments, and occupational dynamics at Quebrada de Amaicha, Tucuman, Argentina

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ABSTRACT

This paper focuses on three interconnected issues: lithic technology, geochronology and climate change, based on rock varnish proxies, and artifact reclamation processes. Ongoing research along the western the semiarid slope of Cumbres Calchaquies–Aconquija ranges and centered in the Amaicha del Valle archaeological locality has focused on lithic surface scatters. These are the product of multiple behavioral events, an accretion phenomena, a palimpsest, areas that were repetitively visited, used, and occupied over the long run for procurement of lithic raw material, manufacture of diverse types of artifacts, and specific activities. Research results suggest, based on typological analysis of lithic surface scatters, a multi-component occupation that may have included site-specific activities. Based on rock varnish microlaminations (VML) studies, a correlation-dating technique that is a reliable time-clock for establishing chronological control, human occupation was already in place prior to 6500–5900 years. Further, rock varnish carries a past climate signal, indicating eight regional wet events for the last 7000 years, four of which are mid-Holocene. Rock varnish differential formation on rocks and artifacts provide additional insights into the occupational dynamics and functionality of sites.

1. Introduction

In the search for new evidence bearing on the general problem of early-to-mid-Holocene human occupation and adaptation to semiarid upland environments, the western piedmont of the Cumbres Calchaquies–Aconquija ranges provided the ideal setting for a challenging archaeological project focused on chronology, past environments, and occupational dynamics of Holocene hunter–gatherers. For this section of the Andes, most, if not all, of what is known today about mid-Holocene hunter–gatherers comes from intensive research centered on the high-altitude *puna* archaeological record. The product has been a vast literature that covers a universe of aspects ranging from lithic technology and taphonomy (e.g., Mondini, 2002; Aschero and Hocsman, 2011) to the material expressions of art (e.g., Aschero, 2007; Gallardo and Yacobaccio, 2007). Although extremely insightful, the explanatory models put forward for mid-Holocene high-altitude hunter–gatherer adaptations, might not adequately deal with the archaeological record of the upland intermountain basins of northwestern Argentina.

Krieger (1964, 1965) advanced the concept of a pre-Clovis cultural stage in the Americas installing, for the whole continent, a model by which early occupants were essentially foragers in possession of a simple flake-stone technology, a pre-projectile point stage that preceded a Clovis Industry. Supporting data, at the time, was that of crudely made stone tools that lacked the technological refinement of bifacially chipped projectile points. The South American evidence included the coastal shell-middens of Taltal in north-central Chile, and the Ampajango Industry or Ampajanguense of northwestern Argentina. The Ampajanguense, specifically as defined (Cigliano et al., 1960; Cigliano, 1961, 1962), was characterized by large, elongate, chopping tools, and a substantial number of bifaces that lacked evidence of pressure flaking. Recovered specimens always came from surface scatters, never appearing in stratified contexts. Along the Santa Maria River valley, the Ampajango type-site lies on top of a Pleistocene-age terrace-system, whereas purported Ampajango flakes and bifaces rest scattered overlaying glacis surfaces along the western slopes of Cumbres Calchaquies and Aconquija ranges. To add complexity,

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a good number of these crude artifacts show a paper-thin dark coating, known as desert-varnish. Although Krieger's construct was discredited early (e.g., Bird, 1965; Wendorf, 1966; Lynch, 1968), Cigliano's alleged pre-Clovis Ampajanguense Industry remained in the body of archaeological thought (e.g., González and Pérez, 2000).

At the time, however, Cigliano and collaborators struggled at dealing effectively with the Ampajanguense record. Methodologically, for example, they were short of survey methods for effectively handling the complexity exposed in open-air sites, where the prevalence of large quantities of lithic artifacts and debitage are exposed in a sort of space-time continuum across large areas. Further, deflated surface deposits were thought to have lost spatial and temporal integrity and, thus, were seen as palimpsests. In addition, many, although not all, Ampajango-like sites lack obvious features and/or the remains of structures, of either ephemeral or more permanent use, that could potentially provide for some sort of intrasite analysis. Finally, even when ^{14}C age determinations were available, both lack of site stratigraphy and suitable organic material hindered its use and the establishment of a chronology. Faced with these limitations hunter–gatherer archaeology, for this section of the Andes, lingered particularly when weighed against the intensive field-research and approaches in theory building that characterized high-altitude *puna* archaeology, both sides of the Andes, during the following years (e.g. Aguerre et al., 1973; Aschero, 1984; Nuñez and Santoro, 1988; Grosjean and Núñez, 1994; Yacobaccio and Morales, 2005).

Nonetheless, several attempts were made in the 1980s by a group of geologists and archaeologists based at the Universidad Nacional de Tucumán. They took, however, a completely different approach, focusing not on artifacts but on the physical landscape and artifact-bearing deposits. They were concerned with the underlying geomorphologic processes and depositional environments as a way to evaluate the geoarchaeological context of the preceramic industries (García Salemi and Durando, 1985; Durando and Platanía, 1988). They carried out fieldwork in the outskirts of Amaicha del Valle, particularly at open-air sites located on the Pleistocene terraces of La Quenquiada, and alluvial fans at Las Salinas (Durando et al., 1986). One of the conclusions was that those sites may have performed as "…*fuentes de aprovisionamiento de materia prima, extracción y reducción primaria en las formas-base…*" and, thus "…serían 'sitios- cantera', en los cuales, más allá de proveerse, se efectuaron tareas de desbaste y formatización inicial de artefactos." (García Salemi et al., 1988, p. 8). In short, they proposed that surface scatters may very well stand for quarry workshops where core preparation-lithic reduction, and primary trimming occurred. Further, they suggested that desert-varnish coating a number of volcanic rocks, including artifacts, might have originated during wetter-than-today conditions, at least 5600 BC (García Salemi et al., 1988).

Most recently, new archaeological intervention (Hocsman et al., 2003; Somonte et al., 2004) at sites along Quebrada de Amaicha (i.e., Campo Blanco) shed new light on surface artifact scatters, now seen as the material remains of an occupational history rather than single episodes of behavior, that determined the content and structure of the assemblage. This approach follows on Schlanger's (1992) 'persistent places' concept of areas repetitively visited, used, and occupied over the long run for the procurement of lithic raw material, manufacture of a diverse type of tools, and carrying out task-specific activities (Somonte, 2005, 2007, 2009; Somonte and Baied, 2011a). The density and range of material on such "structured palimpsests" (sensu Wandsnider, 2004) is always a poor reflection of a traditionally-thought site size and composition at any one point in the past. As Dewar and McBride (1992) pointed out, in the absence of evidence of a permanent occupation (i.e., noticeable through features and/or structures), repeated occupation of the same location but not necessarily the exact same spot would lead to an increase in site area through the accumulation of material belonging to partially overlapping occupations.

The west-facing piedmont of Cumbres Calchaquies–Aconquija ranges is dotted with archaeological sites characterized by overlapping occupational histories, usually surface and less often subsurface artifact scatters that lack organic materials suitable for dating using conventional techniques. They offer, however, specific proxies and markers that are helping to unravel the occupation dynamics of mid-Holocene hunter–gatherers, as well as past regional climate conditions and its effect on resource availability. One of those proxies, rock varnish that coats a number of boulders, cobbles, pebbles, artifacts, features, and structures, alludes also to reclamation processes (Somonte, 2009; Somonte and Baied, 2011a).

As northwestern Argentine archaeology is coming of age, dealing with mid-Holocene hunter–gatherers of the semiarid intermountain basins represents an ultimate challenge. With this in mind, this study focused on three interconnected issues: lithic technology, artifact reclamation processes, and occupation dynamics based on data sets that include samples out of surface lithic artifact scatters recovered at Quebrada de Amaicha. By providing a minimum age estimate for the formation of rock varnish on cobbles and artifacts, varnish microlamination (VML) dating provided geochronological control of artifact scatters. Further, as recovered coated tools exhibit multiple generations of flake scars with varying degrees of varnish, fracture events did not necessarily occur around the same time on a given piece, thus each flaking event is, potentially, a datable event. Likewise, as rock varnish carries a regional climatic signal, a series of Holocene wet and dry events, linked to varnish formation, are here proposed. Together, the study of lithic procurement strategies, technology, and varnish microlaminations provide both fresher insights into the occupation dynamics of mid-Holocene hunters and gatherers of the intermountain basins, and a revisit, with a change in the analytical scale, to the Ampajanguense lithic assemblage.

2. Setting

The study area lies approximately 2000 m above sea level westward of Cumbres Calchaquies–Aconquija Ranges (Fig. 1A), a N–S trending mountain block of Precambrian to early Paleozoic-age, uplifted, and extruded by Miocene events of area-restricted lava-flows (Mon and Mansilla, 1998). The western escarpment and its piedmont are accumulations of Miocene–Pliocene to Quaternary debris-avalanche deposits and sequential mudflows overlying the hard granite bedrock and red and green sandstones of Palaeogene age (Bossi et al., 1984). The resulting piedmont landform is a gently inclined erosional surface thinly covered with fluvial cobbles, pebbles, rounded gravels, and a thin veneer of alluvium. Today, this apparently stable glacis is broken by braided stream channels and covered by a patchwork of vegetation, mostly creosote (*Larrea divaricata*, *L. cunneifolia*) and retamo (*Bulnesia retama*) bushes, a woody taxa locally known as rodajillo (*Plectrocarpa rougesii*), and an array of cacti (e.g. *Trichocereus pasacana*, *Cereus* sp., *Opuntia* sp.) of different shapes and sizes (Perea, 1995). Relatively large alluvial plains such as those that characterize the middle Amaicha and Las Salinas rivers, for example, provide sufficient year-round ground water for arboreal taxa such as mesquite (*Prosopis* spp.), arca (*Acacia visco*), and pimiento (*Schinus molle*).

Climatically, the area today is characterized by a short rainy season with low precipitation (100–200 mm per year), high evaporation rates, low relative humidity (<40% on average), and marked daily and seasonal variations in temperature. Although variability is high (greater than 80%), average precipitation for the

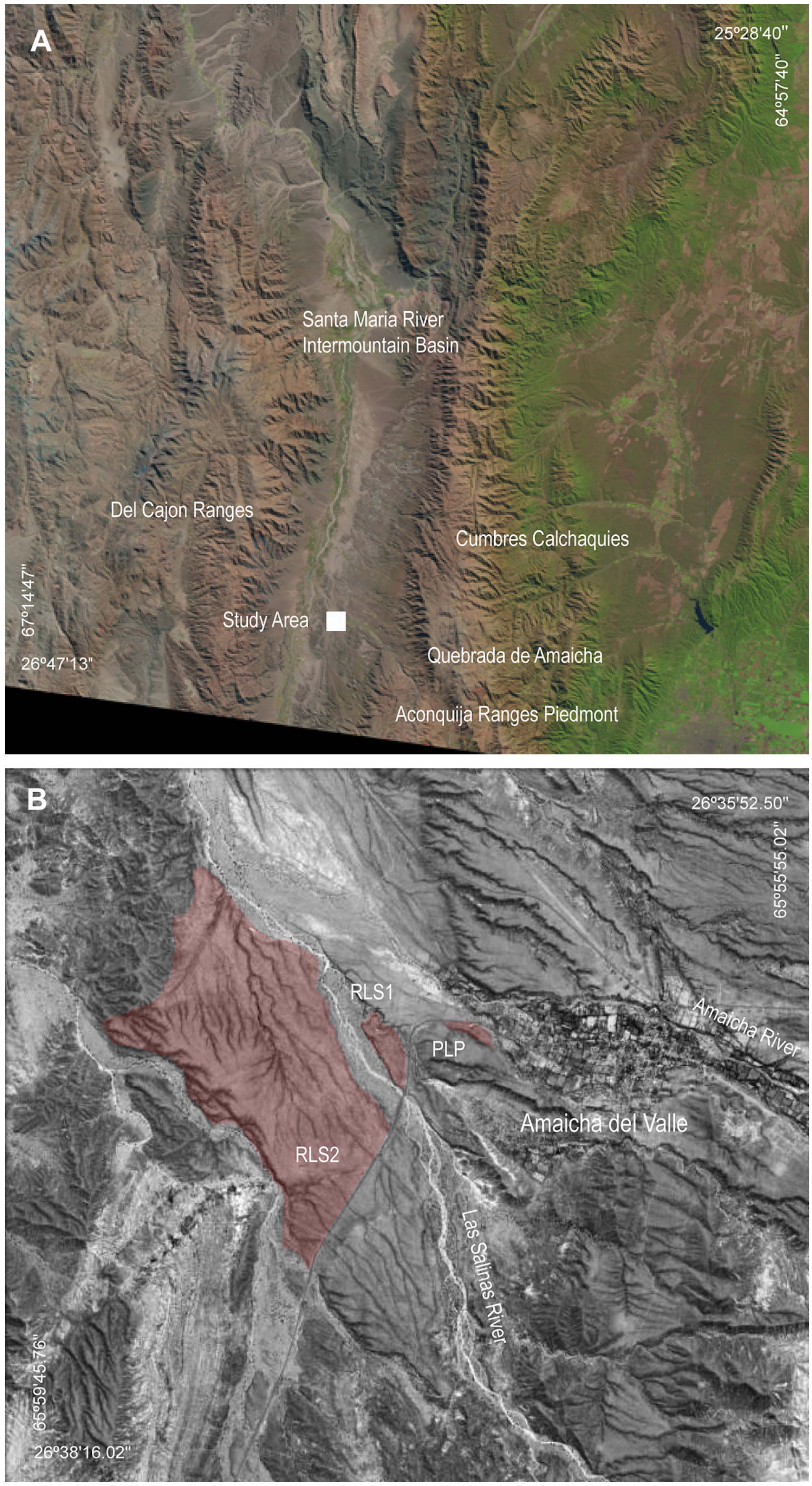

Fig. 1. (A) Aerial view of the Santa Maria intermountain basin. The white rectangle shows the study area in the Quebrada de Amaicha, one of the tributaries of the Santa Maria River. Photo courtesy of NASA (B) Aerial view of the study area. Shaded area shows surface scatters PLP, RLS1, and RLS2. Photo courtesy of Google Earth.

period 1960–1986 at Amaicha del Valle, for example, reached 160 mm with peaks in December, January, and February. As for average temperatures in that same period, lows in July reached 8.9 °C and highs in January 20.2 °C. Under a monsoonal regime, river flow is limited to periods of weeks and linked to either local rainfall or more commonly swift discharges along river-channel floors consequential of upland precipitation (Tineo, 2005). The solid loads of transported materials consist mostly of coarse grade with predominant gravels and sands. These episodic flood events, resulting in erosion in some areas and deposition in others, are a feature of the study area and, together with rill erosion (due to surface water runoff), wind-borne deflation, and mechanical bio-erosion (due to animal burrowing activity and plant-roots growing into cracks); all contribute to the perception of a relatively fast changing landscape. Annual and short-term climatic variations have marked impact on the stability of the landform and, consequently, on the vegetation (species richness and distribution), and human adaptation (strategies for survival).

3. Site formation processes and archaeological sites

Mass wasting, together with wind and pluvial erosion, seasonal water runoff, and stream and river overflows are some of the most significant taphonomic variables at work along the western flanks of Cumbres Calchaquies–Aconquija ranges (Garcia Salemi, 1977) jeopardizing the integrity of the archaeological record. The geomorphic dynamics are such that a land surface is the result of a set of individual erosion and deposition events operating at different temporal and spatial scales. Averaging probably thousand of years, different parts of the landscape will exhibit accumulation of sediments (i.e., predominantly depositional), removal of sediment (i.e., predominantly erosional), or no change (i.e., residual). Maximum exposure of the archaeological record is found in those parts of the landscape that are dominantly residual, while the least exposure is found where deposition and erosion of sediments is dominant. Too much erosion, however, removes the deposits on which artifacts rest effectively obliterating any trace of the archaeological record (i.e., reduced preservation).

The high visibility of the surface record is one of the factors that attracted Somonte to work in the Amaicha del Valle archaeological locality, but interpreting the significance of the quantity of artifacts must be related to the geomorphic history of the sediments on which they rest. Almost all surface deposits in the area are the product of multiple behavioral events, in essence an accretion phenomena or palimpsest, with areas that were repetitively visited, used, and occupied over the long run for the procurement of lithic raw material, manufacture of a diverse type of tools, and carrying out task-specific activities (Somonte, 2009). Because they are aggregated onto a single surface, they are difficult to interpret using standard approaches such as those applied to document and interpret the history of deposition of sediments (i.e., stratigraphy) exposed by excavation. Thus, establishing a chronology for surface deposits until recently has been an intractable problem. To account for postdepositional processes, surface artifact scatters provide an opportunity to study long-term use of places, persistent places (Schlanger, 1992).

Planchada La Puntilla (PLP, ≈1956 m, 26°35′43.21″S, 65°56′17.77″W), and Rio Las Salinas 1 (RLS1, ≈1903 m, 26°35′17.27″S, 65°57′8.14″W) and 2 (RLS2, ≈1885 m, 26°35′12.46″S, 65°57′42.99″W) provide the raw data used in the analysis and interpretation of the archaeological record. All three sites lie in the outskirts of Amaicha del Valle, a mountain hamlet that sits some 2000 m above sea level in the NW corner of the intermountain basin. Although are now set apart by course-ways and alluvial plains of the Amaicha and Las Salinas rivers, surface artifact scatters dot alluvial fans and dissected glacis with unknown rates of rill and gully erosion (Fig. 1B). These surfaces were previously defined as secondary and tertiary sources, of natural and human origin respectively, with clear evidence of exploitation of readily available lithic resources (Somonte and Baied, 2011a). In addition, mound-structures, single-arch stone alignments, purported heat-retaining hearths, and remains of circular-shaped residential units are apparent, mingled within surface scatters. The observed variation in architectural designs, construction techniques, and size (ranging from 1 to 5 m in diameter) does not allow consideration of these features and structures contemporaneous in age. Further, tested and excavated structures failed to provide sub-surface materials except for a few cores and flakes, suggesting short-term occupations probably related to specific–task activities. At PLP, the residential unit (PLP-R4) may well be an exception to the norm, as sediment samples taken during excavation and analyzed for phosphorus, organic matter content, and protein residue has shown two well-defined occupation floors that were not discernible during excavation, the oldest marked by a prepared surface (Somonte, 2009; Coronel, 2011).

Mobile rock-art adds to the complexity of this heterogeneous archaeological landscape. Within all three sites, rock surfaces covered with dark varnish served as the supporting medium for engraved abstract, anthropomorphic, and zoomorphic images with no evidence of superposition of images recorded. Although it is difficult to establish an exact age for this rock-art, it does show differential growth of patinas that, together with contextual information, further contribute to think in terms of persistent places (Somonte et al., 2010).

4. Materials and methods

Archaeological sites were both walked over to maximize the recovery of specific diagnostic artifacts, and systematically surveyed as a way to provide equal and unbiased coverage of the landforms. Systematic survey sampling, a statistically valid technique that allows predictions regarding total resource density, distribution and variability, was conducted over an area defined, primarily, by topographical boundaries (i.e. alluvial plains, gullies). The sampling design in all three sites consisted of a combination of quadrats and transects, a decision that allowed for intensive inspection of difficult areas and for recording features, structures, and mobile rock-art. Survey transects ran North–South, had a 2 m width, and lengths that ranged from 30 m at PLP to 800 m at RLS2. Each transect was then subdivided into 2 m by 2 m quadrats to better control artifact density, dispersion, and variability. Each quadrat, named A1, A2, B1, B2, and so on, became observational units for recording and controlled collection of specimens.

Collecting the right type of sample for VML analysis is critical. Systematic recovery of varnished cobbles, pebbles and artifacts followed the Liu and Dorn (1996) established criteria for rock varnish sampling in the field. Sampling was not based on the field appearance of varnish darkness, estimates of thickness in hand samples, or surface coverage of varnish. Rather, varnish sampling was based only on whether the coated surface retained primary surface features. For example, cobbles and artifacts that showed subaerially exposed varnishes recording their attributes (i.e., composition, shape, size) were collected. In addition, to document the integrity of the surface record at PLP, a 45 m transect transverse to the glacis slope was measured. Along this transect, specimens were collected at 15 cm intervals following the same protocol as during the previous systematic survey carefully recording cobble-pebble/artifact position labeling the exposed surface of each collected specimen. At one end of the transect, sediment samples were collected at fixed intervals every 10 cm in a 40 cm deep test pit, as a way to contextualize the surface sediment record.

Beyond sampling surface specimens, 9 features and remains of ring-shaped and arc-shaped structures of varying diameter were excavated (three at PLP, 2 at RLS1, and 4 at RLS2) following natural deposition levels. Depth averaged 70 cm, reaching in all nine cases a sterile level characterize by a thick layer of carbonate coated, often cemented, (calcrete) buried colluvium. Depositional levels in all structures proved to be sterile with 3 exceptions. At PLP circular structure 4, the sub-surface assemblage amounts to a few cores (five partially varnished out of 10 specimens), and debitage (83 flakes). Tools were completely absent. Sub-circular composite structures 1 and 2 at RLS1 proved to be even less promising, with a total of 22 artifacts recovered. Only 3 cores, 18 debitage flakes, and 1 natural working edge with added traces, add up to the assemblage composition. No tools were recovered during excavation. In addition, one cloth button of men's utilitarian wear was traced to the late XVIII-early XIX Century (Brizzi and Iglesias, 2009, personal communication).

From a methodological standpoint, two levels of analysis were collected. The first is at the lithic assemblage level, in which all recovered lithic material was analyzed as a whole, factoring within, the evaluation of lithic raw material use, variability, and toolkit composition. Typological analysis followed the guidelines put forward by Aschero (1975, 1983) and its revision by Aschero and Hocsman (2004). In Aschero's techno-morphological and morphological-functional typology, the lithic assemblage breaks up in sub-assemblages based on raw material used and 4 tool classes (i.e., cores; tools; artifacts with tips, edges and surfaces with added traces; and debitage), after which the set of specimens is analyzed based on specific variables for each typological class. To address fully the singular character of the Quebrada de Amaicha surface scatters, the sample was split into a third group or sub-assemblage based on varnish-coated lithic artifacts. These specimens were analyzed independently, as differential coatings on flakes are unique snapshots that speaks not only on use but also on artifact reclamation processes, and indirectly, on persistent places.

The second level of analysis is at the geochronological-environmental level, for which exposed varnish-coated lithic material together with the geoform on which they rest serve as proxies for establishing landform surface age estimates and minimum exposure age of archaeological and non-archaeological material. Although relatively novel, the analysis of rock varnish micro laminations is a tested technique (Dorn, 2009) constituting a viable and reliable indicator and an alternative to more traditional geochronological and palaeoenvironmental approaches when dealing surface archaeological scatters. Rock varnish may be defined as a paper-thin coating found on rocks that have been subjected to specific climate conditions, particularly in arid and semiarid regions of the world. It is considered one of the slowest mechanisms of sedimentation, with typical rates of accretion on the order of 1–10 μm per millennia (Dorn, 1998; Liu and Broecker, 2000). Because of its sedimentary origin, rock varnish often displays layered microstratigraphy.

Liu and Dorn (1996), Liu and Broecker (2000, 2007) and Liu (2003) have improved VML dating methods by correlating varnish microlaminations from deserts all over the world. VML correlative dating assumes that the formation of varnish microlaminations is largely influenced by regional climatic variations, and that climatic signals have been recorded as microlaminations of varying color and composition (Liu and Dorn, 1996; Liu et al., 2000). These layers can be identified in thin section, and once the microstratigraphic sequence for a region is defined and calibrated, it is possible to relate the established sequence to thin sections from archaeological specimens, in order to bracket the age of the samples. The most recent VML dating breakthrough resulted from Liu's extension of his calibration from the Late Pleistocene and Terminal Pleistocene into the Holocene (Liu and Broecker, 2007). His study resulted in a replicable Holocene microlamination sequence that consisted of 12 evenly spaced dark layers representing, wet climatic episodes, intercalated with 13 orange/yellow layers, related to dry climatic episodes. As several Holocene geomorphic features were previously dated with AMS ^{14}C and the Greenland Ice Sheet Project Two (GISP2) ice core record, they were able to calibrate the ages of their assigned layering units and correlate them to past climate variations (Liu and Broecker, 2007).

5. Results

What are the measurable markers for early human occupation and climate change in the extant archaeological record of Quebrada de Amaicha? How, within this structured palimpsest, can the early manifestations of behavior be identified? In order to address these questions, the focus was on two distinct but complementary lines of evidence: the lithic assemblage and occupation depth as supported by VML dates on negative flaking scars, and the availability and suitability of varnish-coated lithic artifacts for analysis.

5.1. Lithic assemblage composition

The analyzed data set for this study was obtained from surface lithic artifact scatters that include tools, debitage and cores (Table 1). Selection of locally available raw material for tool production is prevalent (97%) with artifact assemblages predominantly made-up of andesite, quartz, quartzite, and occasional petrified wood. Andesite was the preferred and most common raw materials used in tool manufacturing. Varieties and sources of andesite used were identified in the field, described, and discussed elsewhere (Somonte, 2009; Somonte and Baied, 2011b). Abundant andesite nodules, along with many cores, cortical flakes, bifaces, and unifaces (found in various stages of manufacture), together with differentially varnished flake-negatives, suggests the persistent exploitation of lithic quarries.

Table 1
PLP, RLS1 and RLS2 lithic assemblages organized in typological classes and raw material employed in tool manufacture.

Raw material	Cores		Debitage		Tools		Total by raw material	
	N	%	*N*	%	*N*	%	*N*	%
Andesite	72	14.55	319	64.44	71	14.55	462	93.54
Quartz	2	0.40	18	3.64	1	0.20	21	4.24
Quartzite	–	–	–	–	1	0.20	1	0.20
Petrified wood	–	–	1	0.20	–	–	1	0.20
Chert	–	–	4	0.81	–	–	4	0.81
Non differentiated	2	0.40	2	0.40	1	0.20	5	1.01
Total	76	15.35	344	69.49	74	15.15	494	100

Major typological classes of artifacts include debitage that adds up to 70% of the total assemblage followed by cores and tools with 15% each. Out of the tool inventory ($n = 71$, 100%), 44 are unifaces, 17 of which made out of reclaimed bifaces, and 27 bifacially-flaked tools. Amongst uniface edges, notched flakes, denticulates, choppers, side-scrapers and natural working edges prevail, making up to 85% of the total sample (Table 2). Production of these edges may

Table 2
PLP, RLS1 and RLS2 typological group distribution based on edges in tools.

Typological groups	*N*	%
Notches	19	26.76
Denticulates	15	21.13
Choppers	9	12.70
Side-scrapers	8	11.27
Natural working edges	6	8.45
Tip between notches	4	5.63
Knifes	3	4.22
Rabots	2	2.81
Feather retouched (clustered) and micro-retouched flake-tools	2	2.81
End-scrapers	1	1.41
Unidentified fragments	2	2.81
Total	71	100

have been achieved without involving significant costs. The total assemblage shows tools exceeding 16 cm as being the most common, and a low rate of maintenance and discarding that is probably due to being at the sources, meaning high availability of raw materials in various forms.

As for bifacial tools, Table 3 shows three typological groups (sensu Aschero and Hocsman, 2004): bifaces, leaf-shaped specimens, and bifacial edges with sinuous ridge specimens. Bifaces represent more than 70% of the total sample ($n = 27$), with leaf-shaped and bifacial edges with sinuous ridge representing 25% of the studied specimens. Bifacial tools vary in size, although variation is not significant. Eighty percent of the recovered specimens that have more than 16 cm in length are the most common. Tools size (i.e., module, width) and shape, analyzed by raw material, particularly andesite, suggests procurement of raw material and tool production at the quarry. Elsewhere, it was established that procurement and processing costs are directly related to lithic raw material distribution and availability, and not to accessibility (Somonte, 2009).

Table 3
PLP, RLS1 and RLS2 typological groups and sub-groups in bifaces.

Typological group	Typological sub-group	*N*	*N*	%
Biface	Partial biface	18	19	70.37
	Biface *sensu stricto*	1		
Leaf-shaped specimens	Outline of bifacial piece	7	7	25.93
Bifacial edges with sinuous ridges	–	1	1	3.70
Total		27	27	100

The fact that both unifaces and bifacial tools are reclaimed (sensu Schiffer, 1987), somehow, hinders the identification of specimen's original shape and function. In all specimens, however, the process of taking back large blanks exposing fresh surfaces through removal of old rock varnish, either for edge production or edge-reactivation, is quite evident (Somonte and Baied, 2011b). In addition, a regular pattern of added traces along tool edges are traits that could denote use-ware and a function associated to activities that may have taken place at these sites.

Flaked tools (over 50%) are, in their majority, external or cortical flakes, or retaken flakes. Further, tools and tabular nodules are used as blanks. At first glance, the assemblage suggests that there was no need to obtain specific blanks. It is possible to notice, however, and judging by the size of the instruments, that there was a search for blanks of specific size. In addition to flakes, retaken bifaces used as blanks for manufacturing new instruments may suggest some standardization in terms of what is sought for blanks. Based on the size of retaken and reclaimed flakes, it was possible to notice the need for blanks of exceptional size. Taking into account tool and debitage size, the full assemblage points toward primary and secondary reduction.

Both tested cobbles and cores of exceptional dimensions (>20 cm) are abundant. In general, cores are polyhedric and, apparently, they were never reduced to such an extent that production of suitable flakes was impossible. The core data set shows figures for the final extraction stages that help evaluate when a core was abandoned. Would it be possible that further extraction of adequate size flakes for tool manufacture was not achievable? On the other hand, would it be possible that cores were not yet exhausted? Analysis reveals the presence of cores that show remaining useful life, and this is not surprising but somehow expected in a context of local, readily available raw lithic material. Additionally, the low figures obtained for core rejuvenation flakes support the previous statement.

In summary, the assemblage seems to include all stages of the lithic manufacturing sequence (chaîne opératiore) including procurement of raw material, cores, blanks, debitage, and tools. These activities, however, would have taken place at different occasions and with different emphasis. The first stages of the chaîne opératiore are made evident through the significant proportion of cores and cortical flakes, and the predominance of large-size flakes that are suitable to be used as blanks. Further, the latest stages of the manufacturing sequence are made evident through the byproduct (debitage) of retouch and, in small percentage, edge maintenance or resharpening. At this point, it is possible to suggest that groups visiting these quarry sites manufactured expedient instruments to confront immediate needs, only discarding them once its useful life was exceeded.

Rock varnish coats exposed surfaces of artifacts. Fresher exposures are lighter in color and less recently exposed surfaces have darker or shiny coatings. Lighter colored negative flake scars indicate flakes that have been intentionally removed from cores and bifaces. Almost 90% of recovered tools are coated and all exhibit multiple generations of flake scars, many with varying degrees of varnish indicating that fracture events occurred not necessarily around the same time in a given piece (Somonte, 2009; Somonte and Baied, 2011a,b). In summary, each flaking event is, potentially, a datable event.

5.2. VML dating and palaeoclimatic inferences

As a way to estimate minimum surface exposure age, VML correlative age determination technique was applied to coated rock faces and to negative scars of blanks and tools (Fig. 2). Nine ultra-thin sections removed from 3 specimens gathered at the PLP site were analyzed providing varnish layering sequence that, in principle, correlates with the age scale of radiometrically calibrated and climatically correlated Holocene millennial-scale varnish microstratigraphy of the western USA drylands varnish and the SPECMAP MIS 1 record (Liu, personal communication, 2009).

Based on 5 age determinations, the applied technique provided minimum-limiting surface exposure ages of 7.3–6.5 ka for initial rock varnish formation on rocks and on non-chipped sections of tools. The remaining 4 age determinations performed on the negative scars of tools provided dates that range between 6.5 and 5.9 ka for initial rock varnish formation (Table 4). These dates represent the minimum age of rock varnish formation on lithic artifacts, meaning that artifacts are probably older, although the question remains how old they are, not knowing the time of

Table 4
VML analysis. Results of rock varnish samples from Amaicha del Valle, Tucumán, Argentina.

Rock varnish sample sections	Number of ultra-thin observed	Oldest layering pattern (in cal. yr BP)	Image of oldest layering pattern	VML age estimate[a]
ARG-201-A	1	LU-1 (WH6)	A	5900
ARG-201-B	1	LU-1 (WH6)	B	5900
ARG-201-C	1	LU-1 (WH6+)	C	5900–6500
ARG-202-D	1	LU-1 (WH6)	D	5900
ARG-202-E	1	LU-1 (WH6)	E	5900
ARG-202-F	1	LU-1 (WH7+)	F	6500–7300
ARG-203-G	1	LU-1 (WH6)	G	5900
ARG-203-H	1	LU-1 (WH6+)	H	5900–6500
ARG-203-I	1	LU-1 (WH6+)	I	5900–6500

[a] The VML age estimates are based on a possible, but currently still speculative climatic correlation between the Holocene millennial-scale wet events recorded in rock varnish from the Argentine Andes and the Holocene millennial-scale cooling events recorded in deep sea sediments in the North Atlantic (Liu and Broecker, 2008, personal communication).

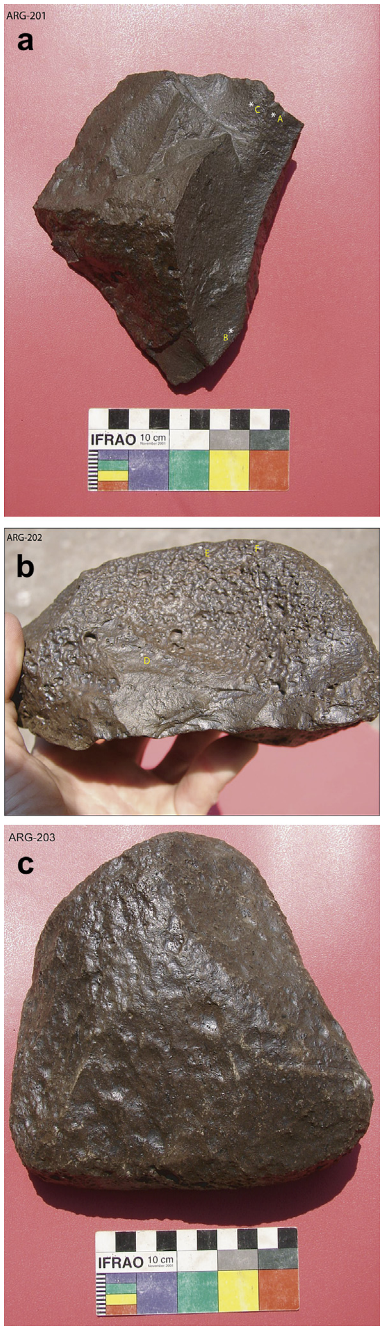

Fig. 2. Rock varnished artifacts and clast from PLP submitted for VML analysis. (a) Nodular flake (ARG-201). Samples for analysis were taken from microbasins A, B, and C; (b) Notch. Samples for analysis were taken from microbasins D, E, and F (ARG-202); (c) Clast. Samples for analysis were taken from microbasins G, H, and I (ARG-203). Arrows point to sites where varnish-filled microbasins were cored by Liu with a mini-drill (4 mm in diameter) for dating.

knapping (Somonte and Baied, 2011b). These dates are, however, the first correlative age determinations for a mid-Holocene lithic tool assemblage from the upland intermountain basins of north-western Argentina.

Beyond chronology, Quebrada de Amaicha varnish micro-lamination studies provided the first reliable data to date on regional mid-Holocene to recent climate change and variability. Within the regional context of widespread arid-to-semiarid conditions, seven wetter intervals (i.e., WH1 to WH7+, from youngest to oldest) bracketed between 7.3 and 0.3 ka were identified. Similar layering patterns are replicated in different varnish microbasins on the same specimen and on different specimens, suggesting that microlaminations in varnish record regional environmental fluctuations (Fig. 3). LU-1 represents an overall thick surface yellow-to-orange layer, indicative of the Holocene interglacial dry climate whereas Holocene wet events are represented by dark layers (WH1–WH7+) in the varnish record. These wet events largely correlate with Holocene cooling events represented by pulses of detrital carbonate in the GISP2 (Bond et al., 1999). Quebrada de Amaicha lie at the transition between two different atmospheric circulations systems given by the Atlantic and Pacific dominant source of moisture. At this latitude, the South American Arid Diagonal, a narrow belt with precipitation less than 250 mm/year (Bruniard, 1982), stretches east of the Andes and west of the Cumbres Clachaquíes – Aconquija Ranges, defining an area were low annual precipitation is due to mountain rain shadow effects. Nonetheless, the Quebrada de Amaicha VML record shows resemblance to numerous Patagonian and south-central Andean palaeoclimatic records that suggest mid-to-late Holocene dominant wet conditions during cold phases in regions located West and South of the Arid Diagonal. Conversely, eastward Pampean archives, such as the Mar Chiquita lagoon palaeohydrological record, indicate that during the Holocene, that region experienced two major mid-to-late Holocene wet and warm episodes between 8.0 and 6.0 ^{14}C ka, and between 4.5 and 2.5 ^{14}C ka, when the lagoon reached its highstands. Dominant dry conditions were observed during cold phases, whereas wet conditions prevailed during warm climatic phases (Piovano et al., 2009). Considering that present-day precipitation at Quebrada de Amaicha occurs almost exclusively during the summer months, the VML palaeoclimatic signal provides to further explore the timing and frequency of climate fluctuations linked to the strength and latitudinal position of the Southern Westerlies during the Holocene.

6. Discussion

In the study area, both geomorphology and human behavior determines preservation, exposure, and visibility of the surface and near-surface archaeological record, and therefore the size and density of archaeological sites. VML correlative age determinations and differential varnish coating on artifact's negative scars support the notion of overlapping occupations since at least 6.5–5.9 ka. Thus, lithic artifact scatters are not the product of a single act of artifact production but rather the result of multiple sequences of production within which *sites* perform as secondary and tertiary sources for lithic procurement (Somonte, 2009; Somonte and Baied, 2011a). An accretion process that is steadily modifying and changing stored data sets that, in turn, reflect upon activities linked to artifact production sequences. Surface artifact scatters at Quebrada de Amaicha, however, may be seen as a structured palimpsest, or as places where a complex sequence of occupations and related activities took place that are recognizable through the differential imprint of varnish coatings combined with typological analysis.

Bryan (1950), for example, suggests that on specific scenarios rock-quarries may have served as places for artifact manufacture focused in the exploitation of specific resources particularly wood and processing of bone. He argues that bifacially-flaked tools, either blanks or rejects, are unfinished instruments though feasible in the exploitation of specific resources. At Quebrada de Amaicha, the occurrence of large biface cores, bifaces, and unifaces calls for production and deposition at the source. This field scenario opens the door for considering these artifacts not as rejects but as instruments used for specific tasks linked to the exploitation of

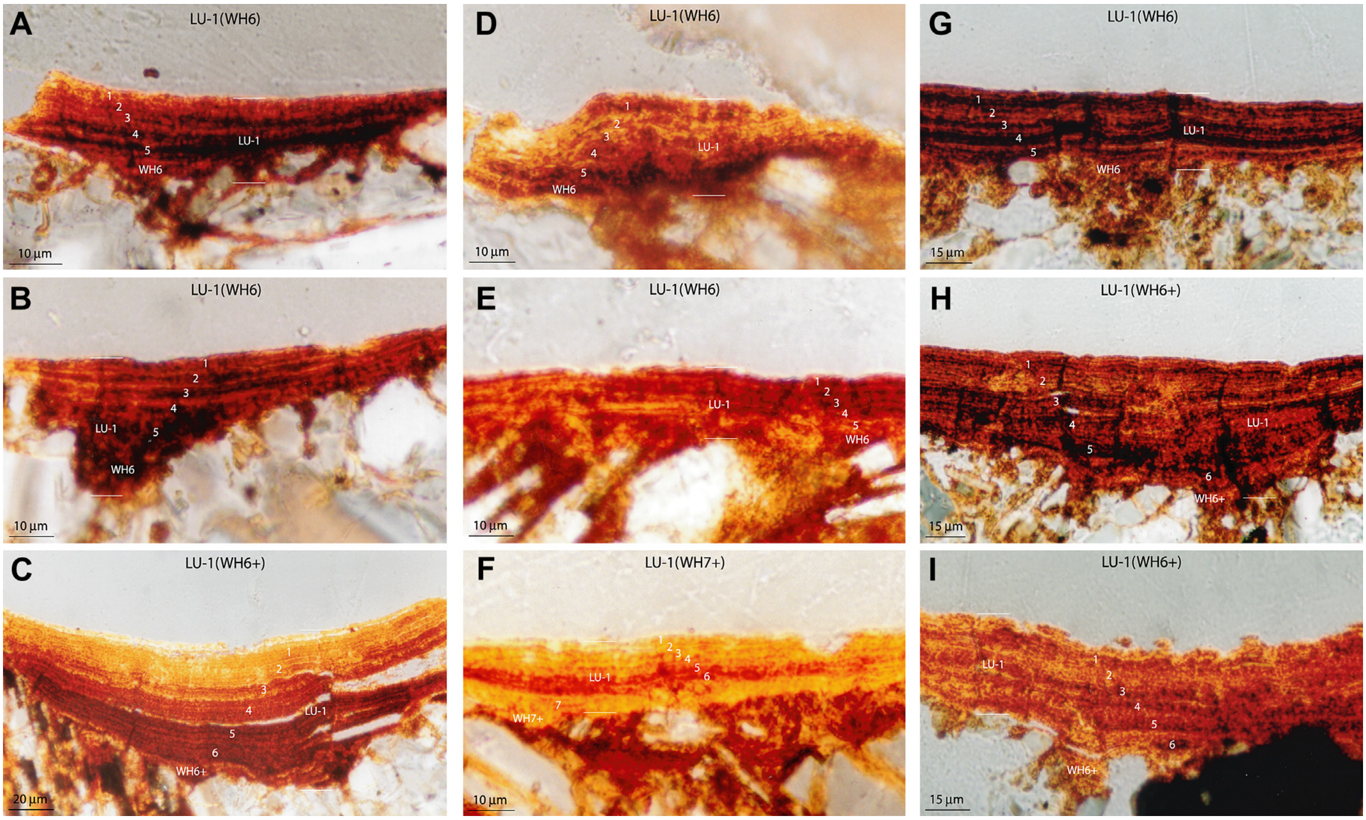

Fig. 3. Optical microstratigraphies in rock varnish from samples ARG-201 (microbasins A, B, C), ARG-202 (microbasins D, E, F) and ARG-203 (microbasins G, H, I). Holocene wet events are represented by dark layers (WH1–WH7+). The color represents relative concentrations of Mn and Ba in varnish microstratigraphy. Dark layers in the varnish are rich in Mn and orange layers are poor in Mn and rich in Fe oxides. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

specific resources. Then, the question is: What resources and tasks are to be linked to these large-size artifacts?

Both ethnohistorical records and oral history provide interesting clues to risk an answer to this question, indicating large areas in the Quebrada de Amaicha and vicinity fully covered with mesquite (*Prosopis* sp.) woodlands. The same is kept in records at the historical archives of Sucre, Bolivia (Quiroga, 2009 personal communication), and in the Relación Histórica de Calchaquí written by the Jesuit priest Hernando de Torreblanca in 1696 (Piossek Prebisch, 1984, p. 96]). De Torreblanca, in particular, refers to competition for territory and resources with regular disputes between two local aboriginal groups, the Pacciocas and the Quilmes, for access to these woodlands.

Although firm data that could support interpolation of ethnographic accounts with vegetation history for periods before contact and colonial times do not exist, it is likely that wet events, as recorded in VML, may have increase species richness and relative species abundance favoring expansion of mesquite forests into areas otherwise barren or short of arboreal taxa. If such is the case, and borrowing from Bryan (1950), both PLP and RLS1 and RLS2 may have performed not only as quarries (i.e., lithic procurement sources) but rather as places were task-specific activities, such as the exploitation of a specific resource (i.e., mesquite) took place. This assumption is supported by the typological characteristics of the lithic assemblage composition, exemplified by choppers, denticulates, side-scrapers, notched flakes, and particularly, large-size bifaces.

Based on the lithic surface scatter assemblages, mid-Holocene hunter–gatherer mobility was probably restricted to a limited given range. There is nothing left behind to suggest a social structured network within a region, a web of alliances and relationships that could provide for other, non-local, lithic resources, judging by the high proportion of andesite-based tools paired with an almost absence of exotics such as obsidian, a common raw material in early Formative regional assemblages. Archaeological research at, for example, Quebrada de los Corrales, one of the tributaries further up Quebrada de Amaicha, does indicate a rich but different mid-Holocene lithic assemblage (Mauri and Martínez, 2009; Martínez et al., 2011), suggesting the possibility of long-distance movement and/or interaction with other groups.

Two major limitations of using VML dating are noted. First, it is a relatively new technique that has only been applied once (this study) to landforms and artifact scatters from Argentina, and second, Holocene varnish microstratigraphy might need to be further calibrated in the intermountain basins of northwestern Argentina where vanished cobbles, pebbles, and artifact scatters are available and suitable for analysis. The age estimates are somehow speculative in nature and subject to refinement and modification in the future depending on changes in the VML age scale for the Argentine varnish. Both limitations are currently being addressed, as the research agenda includes expanding the sampling universe by adding sampling sites within the Quebrada de Amaicha and neighboring area, and collecting suitable specimens for VML analysis. Moreover, Liu's ongoing research is focusing at building a VML age scale for the Argentine west, having already obtained a Holocene varnish layering sequence from morainal boulders in Rio Mendoza and Atuel valleys, and now from cobbles and tools collected at Quebrada de Amaicha (Liu, personal communication, 2009).

7. Conclusions

Several conclusions can be drawn from this study. First, it provides the first correlative dates for lithic surface scatters in the semiarid upland basins of northwestern Argentina. Quebrada de Amaicha record, one that can be typologically linked to the so-called Ampajango industry, provides a limited-minimum VML age estimate of 7300–6500 years and 6500–5900 years for rock varnish formation on rocks and tools respectively. Further, it was possible to identify, from varnish-coated artifacts, evidence of reclamation processes, or a record of multiple behavioral events over a certain period of time for which a firm chronology does not presently exist. Nonetheless, differentially varnished tools are, in essence, snapshots of tool reclamation and potentially suitable for VML dating. Surface lithic scatters in the upland intermountain basins speak of overlapping human occupations that are reconfigured in structured palimpsests.

This paper emphasizes the value of applying VML as a non-conventional dating technique that also carries a past environmental signal. The slowly accumulating rock varnish offers a long-term palaeoclimatic archive for places where other climate proxies are either not available or difficult to read. Seven wet events were recorded, all of which represent environmental changes during the mid-to-late Holocene that have impinged upon the availability of resources. The results underscore the need to reinforce paleoclimate research in an attempt to fully appreciate natural climate variability and its effect on mid-to-late Holocene ecosystems, natural resources, and hunter–gatherer occupational dynamics.

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